Learning Objectives

- 1. Learn about the changes of the updated Illinois Energy Conservation Code (2015 IECC to 2018 IECC).
- 2. Identify the most important Illinois Energy Conservation Code compliance issues in commercial and residential provisions.
- 3. Understand how to comply with the current Illinois Energy Conservation Code for commercial and residential building design and construction.

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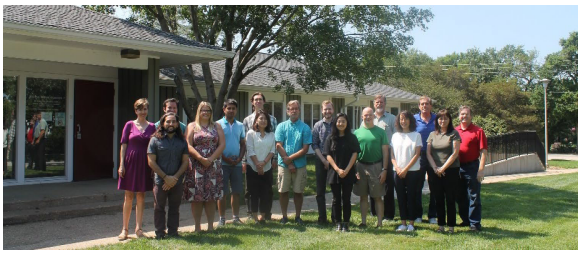
Who we are

- We assist buildings and communities in achieving energy efficiency, saving money, and becoming more sustainable.
- We are an applied research program at University of Illinois, working in collaboration with 360 Energy Group.

Our goal: Reduce the energy footprint of Illinois.



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SEDAC is the Illinois Energy Conservation Code Training Provider

This training program is sponsored by

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ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

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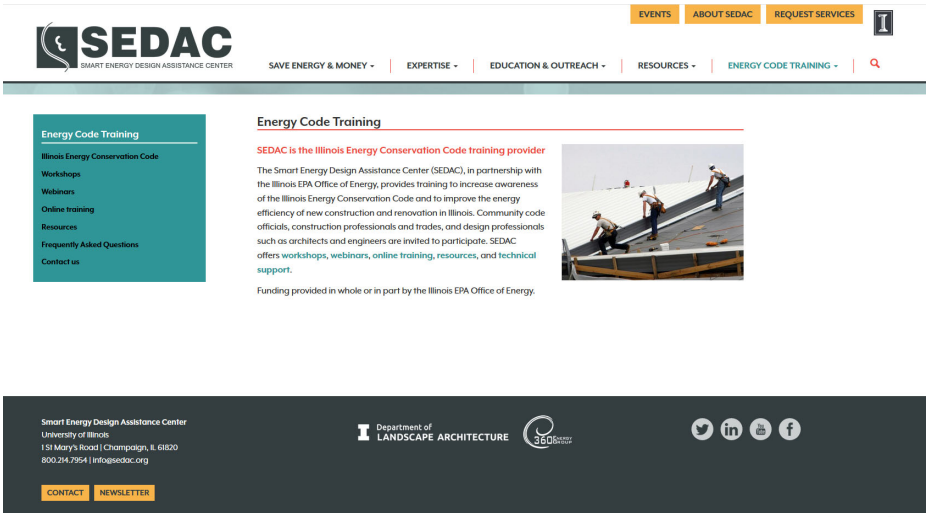

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Illinois Energy Conservation Code

Anticipated adoption date of 2018 IECC: June 1, 2019

In accordance with the Energy Efficient Building Act, the Capital Development Board (CDB) is required to review and adopt the most current version of the International Energy Conservation Code (IECC) within one year of its publication date. The Code will then become effective in Illinois within 6 months following its adoption by the CDB.

The CDB, in conjunction with the Illinois Environmental Protection Agency and the Illinois Energy Conservation Advisory Council, has initiated the cycle for the Illinois Energy Conservation Code to update from the 2015 IECC to the 2018 IECC. It is anticipated at this time that the updated Illinois Energy Conservation Code based on the 2018 IECC and Illinois Amendments will be effective on **June 1, 2019**.

You can access the 2018 IECC here and learn about the 2018 IECC updates in SEDAC's workshops and webinars.

The current Illinois Energy Code is based on the 2015 IECC, with Illinois amendments

The CDB, in conjunction with the Department of Commerce & Economic Opportunity (DCEO), updated the 2012 IECC to the 2015 IECC, and the 2015 IECC, with Illinois Amendments, became law in the State of Illinois on January 1, 2016.

On July 1, 2017, Illinois Executive Order 17-03 transferred responsibility for the Illinois Energy Conservation Code from the Illinois Department of Commerce and Economic Opportunity to the Illinois Environmental Protection Agency (IEPA).

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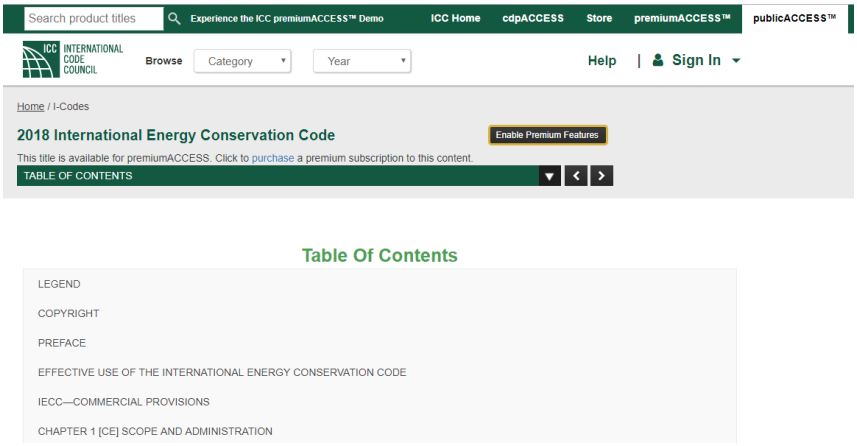
Access to 2018 IECC

https://codes.iccsafe.org/public/document/iecc2018



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Overview of Presentation

1. Overview of Energy codes (genesis to now)
2. Chicago modifications to the code
3. General – Compliance paths
4. Building envelope requirements
5. Additional Efficiency package options

Objectives of Presentation

1. Familiarization with Chicago modifications to the code
2. Understanding of various Compliance paths
3. Highlight important building envelope requirements
4. Clarify Additional Efficiency package options

"If you can't explain it simply, you don't understand it well enough" -- Albert Einstein

Why Care about Codes?

- Energy codes and standards set minimum efficiency requirements for new and renovated buildings, assuring reductions in energy use and emissions over the life of the building. Energy codes are a subset of building codes, which establish baseline requirements and govern building construction.

- Code buildings are more comfortable and cost-effective to operate, assuring energy, economic and environmental benefits.

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Where do energy codes come from?

- In United States – created in response to the energy and economic crises of the 1970s
- 1978 – Congress passed legislation requiring states to initiate energy efficiency standards for new buildings
- 1992 – Energy Policy Act (EPact) – states must review and consider adopting national model energy standard

Source: http://bcap-ocean.org/energycodes101

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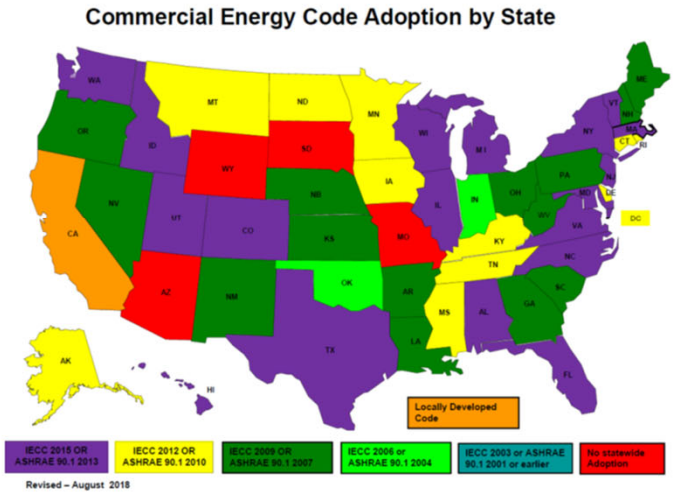
Commercial energy code adoption by state



https://www.nema.org/Technical/FieldReps/Pages/National-Energy-Codes.aspx

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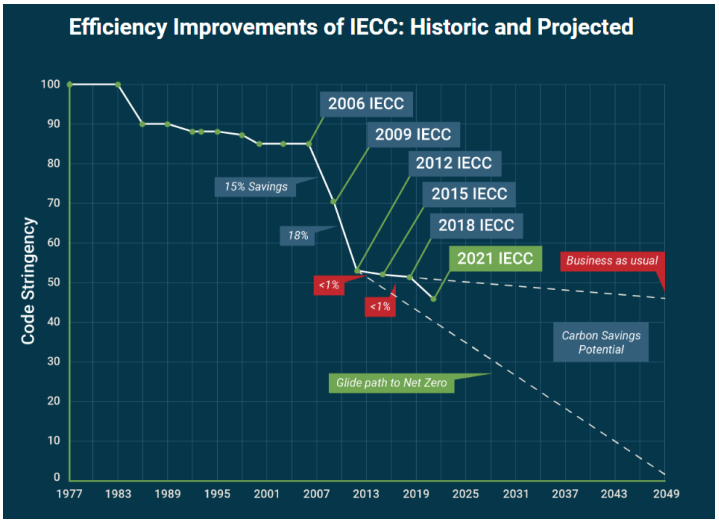
Efficiency improvements of IECC: historic and projected



https://www.greenbuildingsolutions.org/blog/improving-energy-efficiency-codes/

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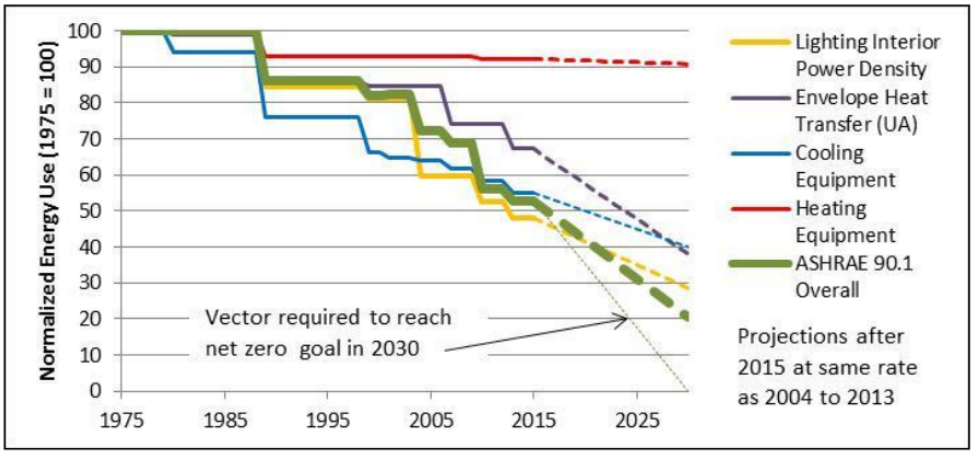
Efficiency improvements by building system



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Roof insulation requirements over time

Comparison of IECC's various editions

Commercial Buildings (Insulation component R-value-based method)

Climate Zone	IECC 2003	IECC 2006	IECC 2009	IECC 2012*	IECC 2015*	IECC 2018*
1	R-12 ci	R-15 ci	R-15 ci	R-20 ci	R-20 ci	R-20 ci
2	R-14 ci				R-25 ci	R-25 ci
3	R-10 ci					
4	R-12 ci		R-20ci			
5	R-15 ci	R-20 ci		R-25 ci	R-30 ci	R-30 ci
6	R-11 ci					
7	R-15 ci	R-25 ci	R-25 ci	R-30 ci	R-35 ci	R-35 ci
8						

* Applies to roof replacement projects
ci = continuous insulation

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High level overview of Codes

- **Building codes are state laws.** The U.S. does not have a national building code or energy code; instead, states or local governments can choose to adopt one of the national model energy codes, a modified version of the model code, or their own state-specific code.
- **Energy codes are just one of many building codes,** such as fire, electrical, structural, or plumbing.
- **Energy codes are different than appliance and equipment standards.** Energy codes cover the building itself—for example, the walls/floors/ceiling insulation, windows, air leakage, and duct leakage. Appliance and equipment standards cover the things that go into the buildings. However, there is some overlap, particularly in lighting.

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Chicago's adoption of energy codes

ARTICLE XIII.
CHICAGO ENERGY CONSERVATION CODE

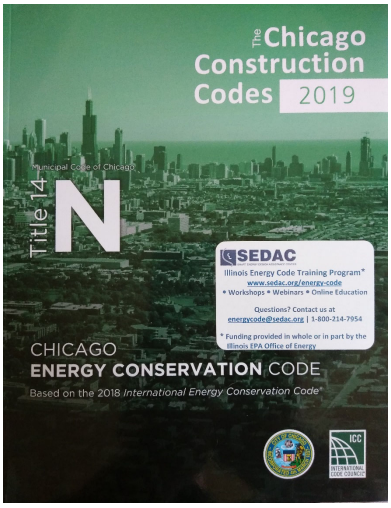
SECTION 1. The Municipal Code of Chicago is hereby amended by inserting a new Title 14N, as follows:

TITLE 14N ENERGY CONSERVATION CODE

PART I – COMMERCIAL PROVISIONS

CHAPTER 14N-C1 SCOPE AND PURPOSE

14N-C1-C001 Adoption of the commercial provisions of the International Energy Conservation Code by reference.



https://www.chicago.gov/content/dam/city/depts/bldgs/general/Energycode/Title%2014N%20ordinance.pdf

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C402.1 General

C101.4 Compliance.

Commercial buildings shall meet the requirements of this code. *Residential buildings* shall meet the requirements of the *Chicago Energy Conservation Code—Residential Provisions.*

C101.4.1 Mixed commercial and residential buildings.
Where a *building* includes both *commercial building* and *residential building* portions, each portion shall be separately considered and meet applicable requirements of this code and the *Chicago Energy Conservation Code— Residential Provisions.*

IECC Chapter 4 Commercial Energy Efficiency

Section	Title
C401	General
C402	Building Envelope Requirements
C403	Building Mechanical Systems
C404	Service Water Heating (Mandatory)
C405	Electrical Power and Lighting Systems
C406	Additional Efficiency Package Options
C407	Total Building Performance
C408	Maintenance Information and System Commissioning

Mandatory requirements need to be complied with regardless of Compliance Path

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IECC Terminology

Prescriptive requirements

are requirements that either must be met by every building design, or if the requirement is not met, a tradeoff must be made to "make up" for not meeting that requirement.

Mandatory requirements

are requirements that must be met in every building design no matter which compliance path is chosen.

Envelope tradeoffs

are tightly defined tradeoffs that allow trades to be made between various parts of the building envelope. i.e. a building owner might choose to install more insulation in the roof to "make up" for putting in more window area than the code allows.

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Commercial Compliance Options

1 ASHRAE 90.1-2016

OR

2 2018 IECC - Prescriptive

- C402 - Envelope
- C403 - Mechanical
- C404 - SWH
- C405 - Lighting

AND

Pick At Least One C406:

- C406.2 – Eff. HVAC Performance
- C406.3 – Reduced Lighting Power
- C406.4 – Enhanced Lighting Controls
- C406.5 – On-site Supply of Renewable energy
- C406.6 – Dedicated Outdoor Air System
- C406.7 – High Eff. Service Water Heating
- C406.8 – Enhanced Envelope Performance
- C406.9 – Reduced Air Infiltration

OR

3 2018 IECC - Performance

- C407 – Total Building Performance
- C402.5 – Air Leakage
- C403.2 – Provisions applicable to all mechanical systems
- C404 - SWH
- Lighting Mandatory Sections
  - C405.2
  - C405.3
  - C405.4
  - C405.6
- Building energy cost to be ≤ 85% of standard reference design building

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Compliance Options - IECC

Prescriptive → R-value table, U-factor table

Trade-off - Envelope → COMcheck

Total building performance → EnergyPlus/Design Builder, Sefaira, TREAT, BSim, etc.

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Section C402 Building Envelope Requirements

Section C402.1.1 Low-energy Buildings

Buildings or portions of buildings that are separated from remainder of building by building thermal envelope assemblies complying with C402 **are exempt** from the Envelope provisions if:

- Peak design rate of energy < 3.4 Btu/h/ft^2 or 1.0 watt/ft^2 of floor area for space conditioning purposes, **OR**
- Those portions or buildings that do not contain conditioned space, **OR**
- Greenhouses

2019 Chicago Building Code, Definition of Greenhouse: a structure or a thermally isolated area of a building that maintains a specialized sunlit environment exclusively used for, and essential to, the cultivation, protection or maintenance of plants

Section C402.1.2 Equipment Buildings

Buildings that comply with the following are exempt from the building thermal envelope provisions:

- Separate building with floor area < 500 ft^2 (50 m^2)
- Intended to house electronic equipment with installed equipment power totaling > 7 watts/ft^2 (75W/m^2)
- Heating system capacity < 17,000 Btu/hr (5 kW) and a heating thermostat set point that is restricted to < 50ºF
- Average wall and roof U-factor < 0.200 in Climate Zones 1-5 and < 0.120 in Climate Zones 6-8
- Comply with the roof solar reflectance and thermal emittance provisions for Climate Zone 1

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14N-C4-C402 Building envelope requirements

- Chicago Energy Code makes 17 changes to Section C402 Building Envelope Requirements

- You will notice that many of the changes that Chicago made to the 2018 IECC are nothing more than elimination of text in the code that does not apply to the Chicago Climate Zone (CZ) or simplification of text.

- The 17 changes are numbered in each slide's heading. Also interspersed throughout this presentation are changes made to the code from the 2015 IECC to the 2018 IECC.

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1. C402.1.2 Equipment buildings

Revise Section C402.1.2 by deleting item 5 and revising item 4 to read:

"Have an average wall and roof U-factor less than 0.200."

Item 4 in 2018 IECC (existing)

- Have an average wall and roof *U-factor* less than 0.200 ~~in *Climate Zones* 1 thru 5 and less than 0.120 in *Climate Zones* 6 through 8~~.

Item 5

- ~~Comply with the roof solar reflectance and thermal emittance provisions for Climate Zone 1.~~

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2 and 3: Table revisions

Revise Table C402.1.3 by deleting all columns except "5 and Marine 4."

Revise Table C402.1.4 by deleting all columns except "5 and Marine 4."

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, R-VALUE METHOD[a, i]

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Roofs																
Insulation entirely above roof deck	R-20ci	R-25ci	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci	R-35ci	R-35ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-49
Walls, above grade																
Mass[g]	R-5.7ci[g]	R-5.7ci[g]	R-5.7ci[g]	R-7.6ci	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci
Metal building	R-13+ R-6.5ci	R-13 + R-6.5ci	R13 + R-6.5ci	R-13 + R-13ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13+ R-19.5ci	R-13 + R-13ci	R-13+ R-19.5ci
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-15.6ci	R-13 + R-7.5ci	R-13+ R17.5ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20+ R-3.8ci	R-13+ R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13+ R-7.5ci or R-20 + R-3.8ci	R13 + R-15.6ci or R-20 + R-10ci	R13 + R-15.6ci or R-20 + R-10ci
Walls, below grade																
Below-grade wall[d]	NR	NR	NR	NR	NR	NR	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-10ci	R-10ci	R-10ci	R-12.5ci
Floors																
Mass[e]	NR	NR	R-6.3ci	R-8.3ci	R-10ci	R-10ci	R-10ci	R-10.4ci	R-10ci	R-12.5ci	R-12.5ci	R-12.5ci	R-15ci	R-16.7ci	R-15ci	R-16.7ci
Joist/framing	NR	NR	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30[f]	R-30[f]	R-30[f]	R-30[f]	R-30[f]
Slab-on-grade floors																
Unheated slabs	NR	NR	NR	NR	NR	NR	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-20 for 24" below
Heated slabs[h]	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-10 for 24" below + R-5 full slab	R-10 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	R-15 for 36" below + R-5 full slab	R-15 for 36" below + R-5 full slab	R-15 for 36" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab
Opaque doors																
Nonswinging	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75

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4. Delete Section C402.2.2 in its entirety

C402.2 Specific building thermal envelope insulation requirements (Prescriptive).

~~**C402.2.2 Above grade walls.** The minimum thermal resistance (R-value) of materials installed in the wall cavity between framing members and continuously on the walls shall be specified in Table C402.1.3. ……..~~

New to 2018 IECC

- C402.2.5 Below-grade walls
  - Insulation used to meet R-value or C-factor shall extend 10ft below grade or to the level of the lowest floor of the conditioned space.
- C402.2.7 Air spaces
  - Where thermal properties of air spaces are used to comply with C401.2, airspaces shall be full enclosed and constructed to minimize airflow through the cavity

5. Delete Section C402.3 and all its subparts

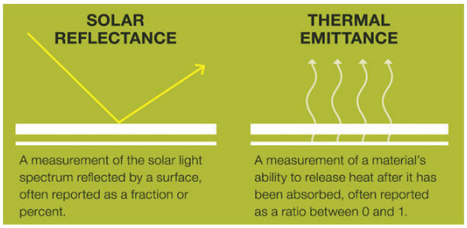
~~C402.3 Roof solar reflectance and thermal emittance……~~

6. C406. Delete Table C402.3

~~TABLE C402.3~~
~~MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]~~

Three-year-aged solar reflectance index[b] of 55 and 3-year aged thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64

~~a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for either solar reflectance or thermal emittance shall be assigned both a 3-year-aged solar reflectance in accordance with Section C402.3.1 and a 3-year-aged thermal emittance of 0.90.~~
~~b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-S100.~~
~~c. Aged thermal emittance tested in accordance with ASTM C1371 or ASTM E408 or CRRC-S100.~~
~~d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h • ft² • °F (12W/m² • K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.~~



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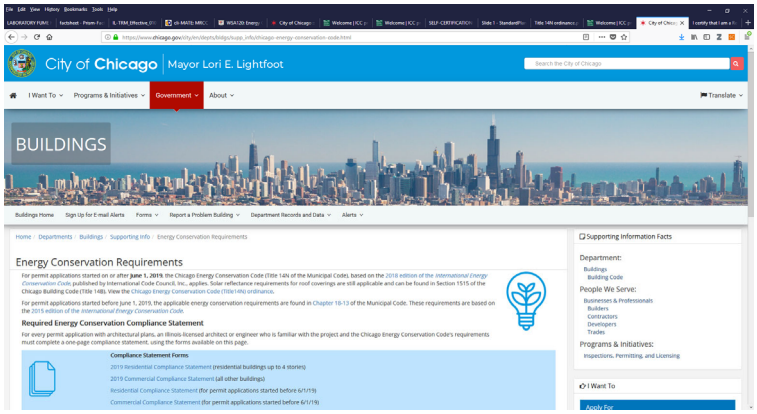
City of Chicago Department of Buildings website



https://www.chicago.gov/city/en/depts/bldgs/supp_info/chicago-energy-conservation-code.html

For every permit application with architectural plans, an Illinois-licensed architect or engineer who is familiar with the project and the Chicago Energy Conservation Code's requirements must complete a one-page compliance statement, using the forms available on this page.

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2019 Chicago Building Code

Section 1515
Solar Reflectance

1515.1 Scope. *Roof Coverings* shall comply with the solar reflectance requirements in Section 1515.2

Exceptions:

1. Walking surfaces on *occupiable roofs*
2. *Vegetative roofs*, roof gardens and landscaped roofs
3. Photovoltaic and solar thermal equipment

1515.2 Solar reflectance. All *roof Coverings* shall have a minimum solar reflectance as specified in Sections 1515.2.1 or 1515.2.2 as demonstrated by:

1. Testing in accordance with ASTM E903 or ASTM E1918.
2. Testing with a portable reflectometer at near-ambient conditions
3. A label from the Cool Roof Rating Council.
4. Labeled Energy Star-qualified roof product.

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2019 Chicago Building Code

1515.2.1 Low-sloped roofs. Roof coverings on low-sloped roofs shall have an initial reflectance value of 0.72 or a three-year-installed reflectance value of 0.5 or greater.

Exceptions:

1. Where more than 50% of the roof area is a vegetative roof or roof garden, the remainder of the roof area shall have a three-year-installed reflectance of 0.3 or greater.
2. Roofs with a minimum of 15 pounds per square foot of ballast installed over the entire roof area to resist wind uplift shall have a three-year-installed reflectance value of 0.3 or greater.

1515.2.2 Other than low-sloped roofs. *Roof coverings* on other than *low-sloped roofs* shall have an initial reflectance value of 0.15 or greater.

Exceptions:

1. *Roof coverings* installed with a slope of 5:12 or greater.
2. *Historic buildings*.

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7. Revise Table C402.4 (by deleting all columns except 5 and Marine 4)

Table simplification

Table C402.4
Building Envelope Fenestration Maximum
U-factor and SHGC Requirements

CLIMATE ZONE	5 AND MARINE 4	
Vertical fenestration		
U-factor		
Fixed fenestration	0.38	
Operable fenestration	0.45	
Entrance doors	0.77	
SHGC		
Orientation[a]	SEW	N
PF < 0.2	0.38	0.51
0.2 ≤ PF < 0.5	0.46	0.56
PF ≥ 0.5	0.61	0.61
Skylights		
U-factor	0.50	
SHGC	0.40	

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Removing references to other Climate Zones

8. Revise the first sentence of Section C402.4.1.1 to read:

~~In *Climate Zones* 1 through 6,~~"Not more than 40 percent of the gross above grade wall area shall be vertical fenestration, provided that all of the following requirements are met:"

9. Revise Section C402.4.2 [Minimum skylight fenestration area] by deleting item 1 in the exception.

Exception: ~~1. Buildings in Climate Zones 6 through 8.~~

10. Revise Section C402.4.3.1 to read:

~~In *Climate Zones* 1 through 6,~~"Skylights shall be permitted a maximum SHGC of 0.60 where located above *daylight zones* provided with *daylight responsive controls*."

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Removing references to other Climate Zones again

11. Revise Section C402.4.3.2 [increased skylight U-factor] to read:

"Where skylights are installed above *daylight zones* provided with *daylight responsive controls*, a maximum U-factor of ~~0.9 shall be permited in Climate Zones 1 through 3 and a maximum U-factor of~~ 0.75 shall be allowed." ~~permitted in Climate Zones 4 through 8.~~

12. Revise Section C402.5.1 [air barriers] by adding the following after the last sentence:

"For roof air barriers on existing buildings, refer to Section C503.1 or C504.2."

Section C503 Alterations

Section C504 Repairs

13. Delete the exception to Section C402.5.1.

Exception: ~~Air Barriers are not required in buildings located in *Climate Zone* 2B.~~

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Addition of text

14. Revise Section C402.5.1.1 (air barrier construction), item 3 to read:

"Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Sealing shall allow for expansion, contraction and mechanical vibration. Paths for air leakage from the building to the space between the roof deck and roof covering used air barrier shall be caulked, gasketed or otherwise covered with a moisture vapor-permeable material. Joints and seams associated with penetrations shall be sealed in the same manner or taped. Sealing materials shall be securely installed around the penetration so as not to dislodge, loosen or otherwise impair the penetrations' ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation. Sealing of concealed fire sprinklers, where required, shall be in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings."

- *New text per Chicago Code

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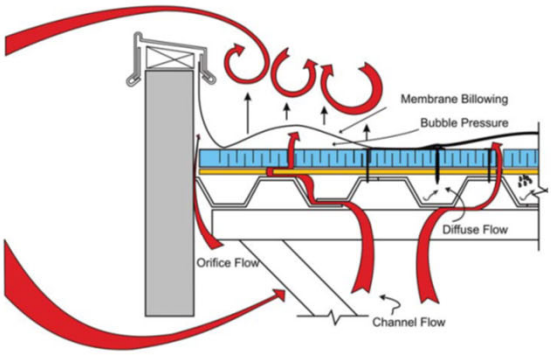
Air intrusion vs. leakage



Billowing of roof membrane can cause air intrusion from the interior into roof assembly.

http://rci-online.org/wp-content/uploads/2009-11-baskaran-molleti.pdf

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Removing references to other Climate Zones again

15. Revise Section C402.5.1.1 (Air Barrier construction), item 4 to read:

Item 4 "Recessed lighting fixtures shall comply with Section C402.5.8. Where similar objects are installed that penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier." This is the exact same language as in the IECC (?!).

16. Revise the first sentence of Section C402.5.3 (Rooms containing fuel-burning appliances) to read:

~~In Climate Zones 3 through 8,~~ "Where combustion air is supplied through openings in an exterior wall to a room or space containing a space-conditioning fuel-burning appliance, one of the following shall apply:"

17. Revise Section C402.5.7 (Vestibules) by deleting exception item 1.

Exception: ~~1. Buildings in Climate Zones 1 and 2.~~

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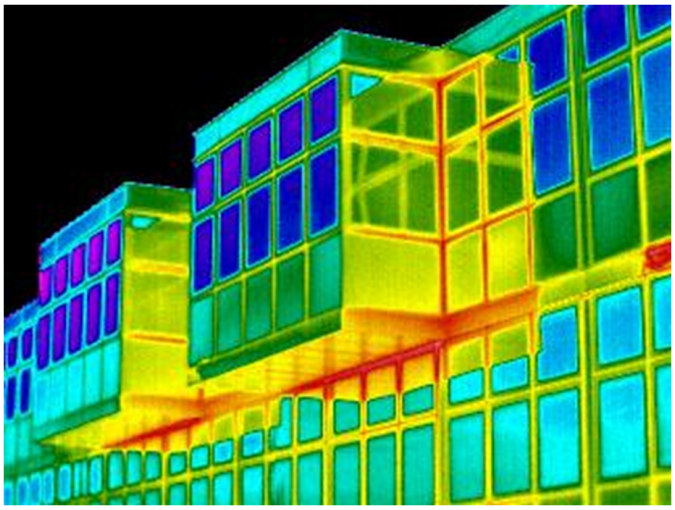
IECC C402 – Building Thermal Envelope



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IECC R402 – Building Thermal Envelope

R402.1 General (Prescriptive)

Building thermal envelope to comply with the following:

- Specific insulation requirements of Section C402.2
- Thermal requirements of either:
  - R-value-based method of Section C402.1.3
  - U-, C-, and F-factor-based method of Section C402.1.4 OR
  - Component performance alternative of Section C402.1.5
- ~~Roof solar reflectance and thermal emittance (C402.3)~~
- Fenestration in building envelope assemblies (C402.4)
- Air Leakage of building envelope assemblies (C402.5)

Envelope Compliance Paths

C402.1.3 C402.1.4	Prescriptive	R-value table U-factor table
C402.1.5	Trade-off Envelope	COMcheck
C407	Total building performance	EnergyPlus/Design Builder, Sefaira, TREAT, BSim, etc.

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Method 1: C402.1.3 Insulation component R-value-based method

Building thermal envelope opaque assemblies shall comply with the requirements of Section C402.2 and C402.4.

R-values for insulation shall not be less than that specified in Table C402.1.3.

- C402.2 Specific building thermal envelope insulation requirements (Prescriptive).
- C402.4 Fenestration (Prescriptive)

Table C402.1.3 Excerpt

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Roofs		
Insulation entirely above roof deck	R-30ci	R-30ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-49
Walls, above grade		
Mass[g]	R-11.4ci	R-13.3ci
Metal building	R-13 + R-13ci	R-13 + R-13ci
Metal framed	R-13 + R-7.5ci	R-13 + R-7.5ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci
Walls, below grade		
Below-grade wall[d]	R-7.5ci	R-7.5ci
Floors		
Mass[e]	R-10ci	R-12.5ci
Joist/framing	R-30	R-30
Slab on-grade floors		
Unheated slabs	R-10 for 24" below	R-10 for 24" below
Heated slabs[h]	R-15 for 36" below + R-5 full slab	R-15 for 36" below + R-5 full slab
Opaque doors		
Nonswinging	R-4.75	R-4.75

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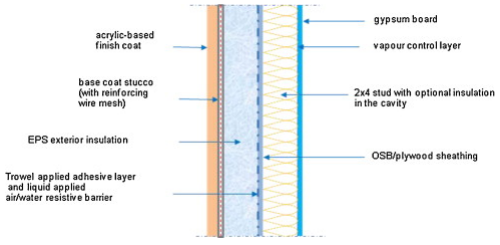
Method 2: C402.1.4 Assembly U-factor, C-factor or F-factor-based method

Building thermal envelope opaque assemblies shall comply with the requirements of Section C402.2 and C402.4.

Building thermal envelope opaque assemblies intended to comply on an assembly U-, C- or F-factor basis shall have a U-, C- or F-factor not greater than specified in Table C402.1.4.



CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Roofs		
Insulation entirely above roof deck	U-0.032	U-0.032
Metal buildings	U-0.035	U-0.035
Attic and other	U-0.027	U-0.021
Walls, above grade		
Mass[g]	U-0.090	U-0.080
Metal building	U-0.052	U-0.052
Metal framed	U-0.064	U-0.064
Wood framed and other[c]	U-0.064	U-0.064
Walls, below grade		
Below-grade wall[c]	C-0.119	C-0.119
Floors		
Mass[d]	U-0.074	U-0.064
Joist/framing	U-0.033	U-0.033
Slab on-grade floors		
Unheated slabs	F-0.54	F-0.54
Heated slabs[f]	F-0.79 0.64	F-0.79 0.64
Opaque doors		
Swinging door	U-0.37	U-0.37
Garage door <14% glazing	U-0.31	U-0.31

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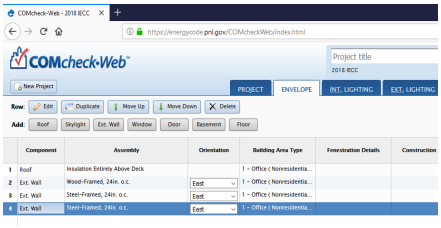
Method 3: C402.1.5 Component performance alternative

Building envelope values and fenestration areas determined in accordance with Equation 4-2 shall be an alternative to compliance with the U-, F- and C-factors in Tables C402.1.4 and C402.4 and the maximum allowable fenestration areas in Section 402.4.1. Fenestration shall meet the applicable SHGC requirements of Section C402.4.3



A + B + C + D + E ≤ Zero (Equation 4-2)

THIS IS WHAT'S BEHIND THE SCENES IN COMCHECK. THIS IS ONLY FOR THE THERMAL ENVELOPE! Trade offs are allowed in the envelope.

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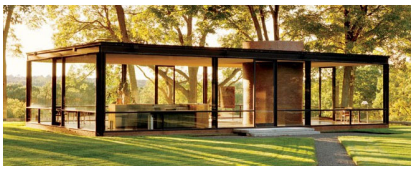
Method 4: C407 Total Building Performance alternative

Compliance based on total building performance requires that a proposed building (proposed design) be shown to have an annual energy cost that is less than or equal to the annual energy cost of the standard reference design.

Exception: Jurisdictions that require site energy (1 kWh=3,413 Btu) rather than energy cost as a metric of comparison.

Standard reference design



Proposed design

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C402.2 Specific building thermal envelope insulation requirements

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Section C402.2.1 Roof Assembly

Roof R-values and U-factor requirements are based on assembly type / insulation placement

- Insulation entirely above deck
- Metal buildings
- Attic and other

Excerpt from Table C402.1.3

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Insulation entirely above roof deck	R-30ci	R-30ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-49

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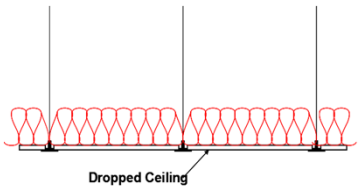
C402.2.1 Roof assembly

- Insulation installed on a suspended ceiling having removable ceiling tiles shall not be considered as part of the minimum thermal resistance of the roof insulation..



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Envelope [C402.2.1]

Roof Assembly

New to the 2018 IECC:

Continuous insulation board shall be installed in not less than 2 layers and the edge joints between each layer of insulation shall be staggered.

Exceptions:
3. Two layers of insulation are not required where insulation tapers to the roof deck, such as at the roof drains.

Excerpt from Table C402.1.3

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Insulation entirely above roof deck	R-30ci	R-30ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-49

Image courtesy of Pacific Northwest National Labs

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Envelope [C402.2.1]

Tapered Roof Insulation

Where tapered insulation is used with insulation entirely above deck, insulation may not vary more than 1" from the R-value specified in C402.1.3.

Excerpt from Table C402.1.3

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Insulation entirely above roof deck	R-30ci	R-30ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-49

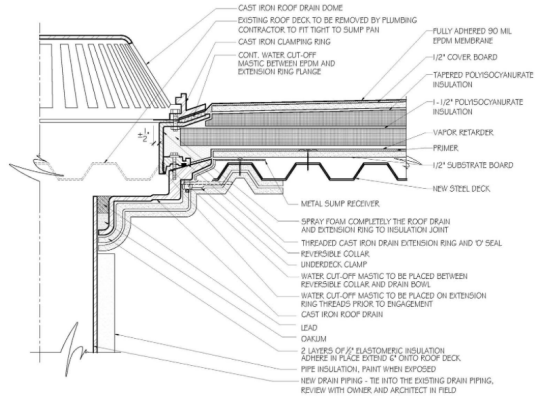

FIGURE 3 - NEW ROOF DRAIN DETAIL - METAL ROOF DECK

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Envelope [C402.2.1]

Metal Building Roof Insulation

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Insulation entirely above roof deck	R-30ci	R-30ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-49

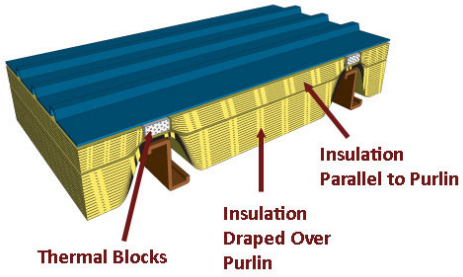

Image courtesy of MBCI article Dec. 16, 2015

b. Where using R-value compliance method, a thermal spacer block shall be provided, otherwise use the U-factor compliance method in Table C402.1.4.

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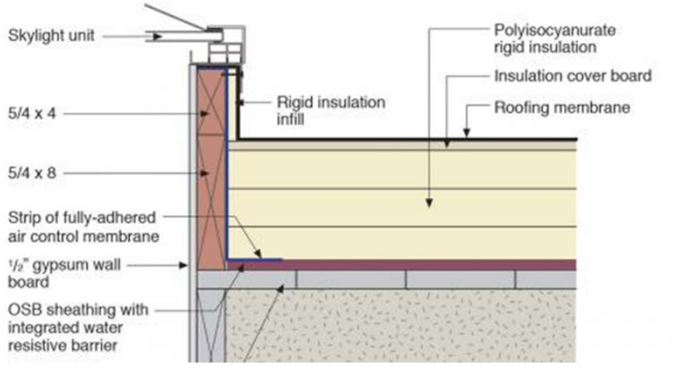
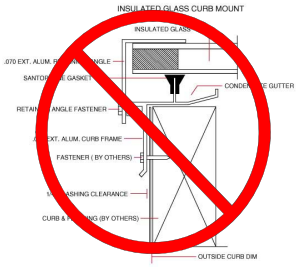
C402.2.1.1 Skylight curbs

- Skylight curbs shall be insulated to the level of roofs with insulation entirely above the deck or R-5, whichever is less.

Exception: Unit skylight curbs included as a component of a skylight listed and labeled in accordance with NFRC 100 shall not be required to be insulated.





From DOE Build America Solutions Center: https://basc.pnnl.gov/images

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Envelope [C402.1.3]

Heated Slab Insulation

Added to the 2018 IECC: R-5 continuous insulation required under heated slabs for both commercial and residential

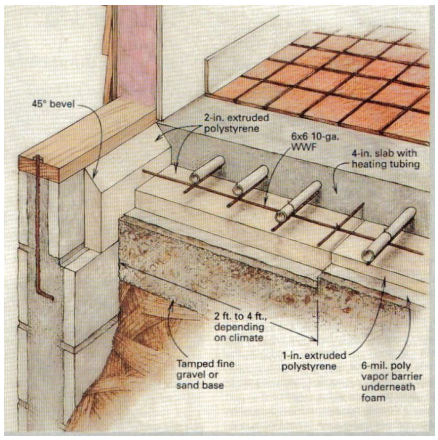

Table C402.1.3
Opaque Thermal Envelope Insulation Component Minimum Requirements, R-Value Method

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Floors		
Mass[e]	R-10ci	R-12.5ci
Joist/framing	R-30	R-30
Slab-on-grade floors		
Unheated slabs	R-10 for 24" below	R-10 for 24" below
Heated slabs[h]	R-15 for 36" below + R-5 full slab	R-15 for 36" below + R-5 full slab

h. The first value is for the perimeter insulation and the second value is for slab insulation. Perimeter insulation is not required to extend below the bottom of the slab.

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Envelope [C402.1.4]

Garage Door Glazing

Added to the 2018 IECC:

A U-factor of .31 has been added to table C402.1.4 as a minimum requirement for garage doors with glazing <14%

But what about garage doors with glazing >14%? Treated as vertical fenestration?

C402.4.5 Doors...Other doors shall comply with the provisions of Section C402.4.3 for vertical fenestration.

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Envelope [C402.2.5]

Below-grade walls

New to 2018 IECC:

New section on below grade walls includes C-factor and R-value

C-factor is inverse of R-value

C-factor of .119 = 1/8.4 R-value

	Table C402.1.3		Table C402.1.4	
Climate Zone	5 And Marine 4		5 And Marine 4	
	All Other	Group R	All Other	Group R
	Walls, below grade			
Below Grade Walls[c]	R – 7.5ci	R – 7.5ci	C-0.119	C-0.119

Footnote C: Where heated slabs are below grade, below-grade walls shall comply with the U-factor requirements for above-grade mass walls.

The C-factor or R-value required shall extend to a depth of not less than 10 feet below the outside finished ground level, or to the level of the lowest floor of the conditioned space enclosed by the below-grade wall, whichever is less.

By IL amendment, residential foundation insulation can stop 6" above the finished floor level in basements.

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Envelope [C402.2.7]

Airspaces

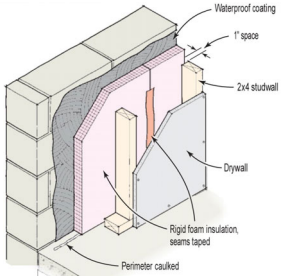
New to the 2018 IECC:

New section provides guidance on treatment of airspaces:

When the thermal properties of airspaces are calculated as part of the thermal wall assembly, these airspaces must be enclosed in an unvented cavity designed to minimize airflow into and out of the cavity.

Cavity shall be enclosed,

unventilated, and sealed



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Envelope [C402.4.1]

Maximum [Fenestration] Area

https://commons.wikimedia.org/w/index.php?curid=287098

- Maximum fenestration area is 30% unless the requirements of additional daylight responsive controls are implemented and then not more than 40% provided all of the following requirements are met:
  1. No less than 50% of the conditioned floor area is within a daylight zone in buildings ≤ 2 stories above grade
  2. In buildings three or more stories above grade, not less than 25% of the net floor area is within a daylight zone
  3. Daylight responsive controls complying with C405.2.3.1 are installed in daylight zones
  4. VT of vertical fenestration is not less than 1.1 times SHGC
- Exception:

Fenestration that is outside the scope of NFRC 200 isn't required to comply with VT

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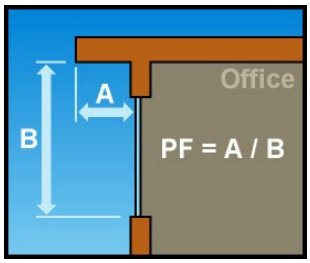
C402.4 Fenestration (Prescriptive)

Table C402.4 Building Envelope Requirements
Fenestration Maximum U-factor and SHGC

CLIMATE ZONE	5 AND MARINE 4	
Vertical fenestration		
U-factor		
Fixed fenestration	0.38	
Operable fenestration	0.45	
Entrance doors	0.77	
SHGC		
Orientation[a]	SEW	N
PF < 0.2	0.38	0.51
0.2 ≤ PF < 0.5	0.46	0.56
PF ≥ 0.5	0.61	0.61
Skylights		
U-factor	0.50	
SHGC	0.40	



PF = Projection Factor
"N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N".

What is Solar Heat Gain Coefficient?

The ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation.

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Envelope [C402.4]

NFRC Label - SHGC

World's Best Window Co.
Series "2000"
Casement
Vinyl Clad Wood Frame
Double Glazing•Argon Fill•Low E
XYZ-X-1-00001-00001

National Fenestration Rating Council® CERTIFIED

ENERGY PERFORMANCE RATINGS

U-Factor (U.S. / I-P)	Solar Heat Gain Coefficient
0.35	**0.32**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S. / I-P)
0.51	**≤0.3**
Condensation Resistance	
51	**–**

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org

- **U-Factor** measures how well a product can keep heat from escaping from the inside of a room. The lower the number, the better a product is at keeping heat in.
- **Solar Heat Gain Coefficient** measures how well a product can resist unwanted heat gain, which is especially important during summer cooling season. The lower the number, the less you'll spend on cooling.
- **Visible Transmittance** measures how well a product is designed to effectively light your home with daylight, potentially saving you money on artificial lighting. The higher the number, the more natural light is let in.
- **Air Leakage** measures how much air will enter a room through a product. The lower the number, the fewer drafts you'll experience.
- NFRC also has a **condensation rating** that is optional for manufacturers to include, so you may or may not see it on the label. The higher the number, the better a product resists condensation.

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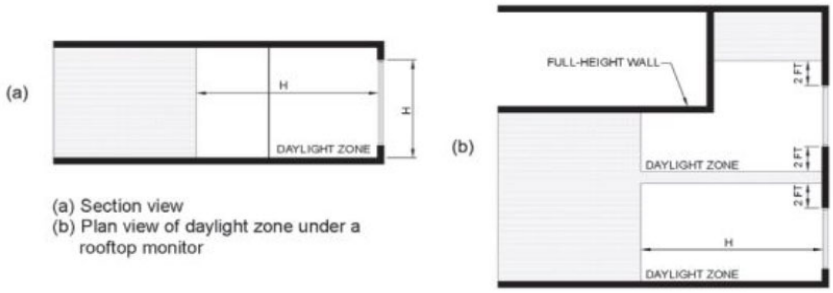
Image courtesy of National Fenestration Rating Council

Electric Power and Lighting Systems
[C405.2.3.2]

Sidelit Zones

The sidelit zone is the floor area adjacent to vertical fenestration.



(a) Section view
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.3.2
SIDELIT ZONE

Image courtesy of International Code Council

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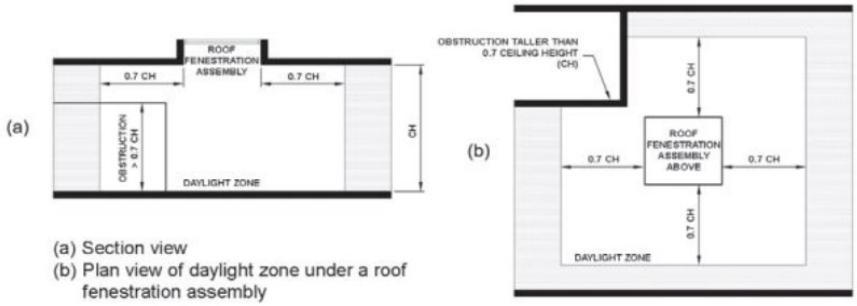
Electric Power and Lighting Systems
[C405.2.3.3]

Toplit Zone

The toplit zone is the floor area underneath a roof fenestration assembly.



(a) Section view
(b) Plan view of daylight zone under a roof fenestration assembly

FIGURE C405.2.3.3(1)
TOPLIT ZONE

Image courtesy of International Code Council

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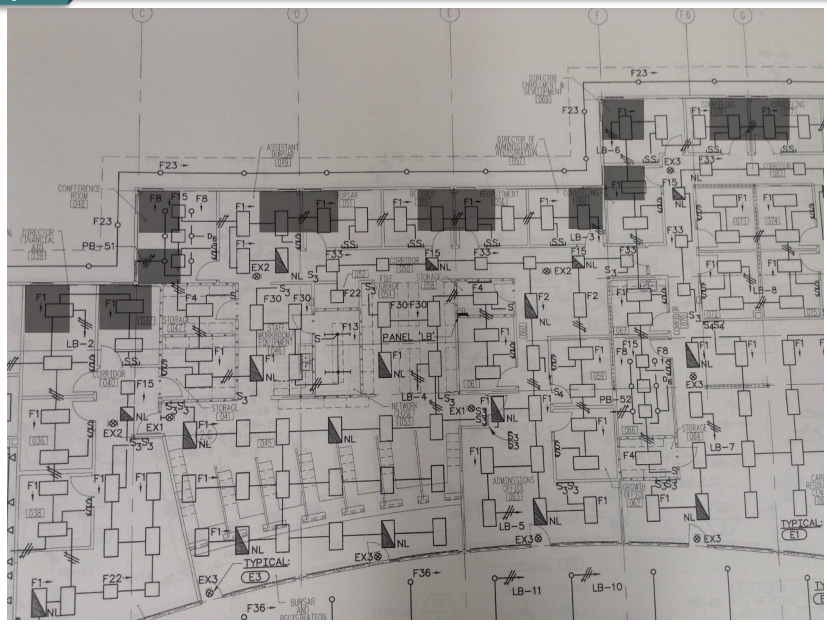
Electric Power and Lighting Systems [C405.2.3.3]

C405.2.3.2 Sidelit Zones



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Envelope [C402.4.1.2]

Skylight Fenestration Area

2018 IECC Increases maximum skylight area limit to 6 percent of the roof area provided *daylight response controls* complying with Section C405.2.3.1 are installed in *toplit zones*.

Image courtesy of DOE

Minimum skylight area in spaces over 2,500 square feet with at least 75% of the ceiling over 15' and used for one of the space types listed.

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Section C402.4.5 Doors

Opaque swinging doors having < 50% glass area

Comply with Table C402.1.4

Opaque nonswinging doors

✓Comply with Table C402.1.3

All other doors to comply with vertical fenestration requirements (Section C402.4.3)

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C402.5 Air Leakage Requirements (Mandatory)

The thermal envelope of buildings shall comply with Sections C402.5.1 through C402.5.8 or the building thermal envelope shall be tested in accordance with ASTM E 779 at a pressure of 0.3" water gauge (75pa) … Air leakage rate of the building thermal envelope is not greater than 0.40 cfm/ft2

Two main options for to establish that there is limited air leakage in the building's thermal envelope

1. design and construct the building in compliance with the detailed requirements of Sections C402.5.1 through C402.5.8

2. test the 'tightness' of the envelope in accordance with ASTME779. Must also comply with C402.5.5, C402.5.6 and C402.5.7.

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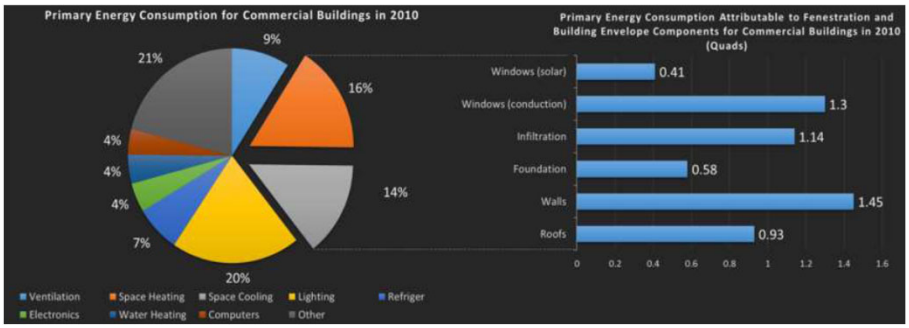
The impact of infiltration

The commercial building envelope is the primary determinant of the amount of energy required to heat, cool, and ventilate a building



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Section C402.5.1.1 Air Barrier Construction

- Continuous air barrier required except in:
  - Climate Zone 2B
- Air barrier placement allowed:
  - Inside of building envelope
  - Outside of building envelope
  - Located within assemblies composing envelope OR
  - Any combination thereof
- Continuous for all assemblies part of the thermal envelope and across joints and assemblies
- Joints and seams sealed including sealing transitions in places and changes in materials, securely installed in or on the joint for its entire length to not dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation

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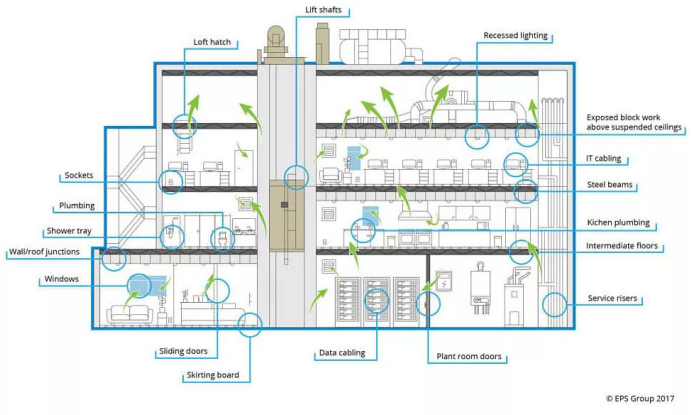
Section C402.5.1.2 Air Barrier Compliance Options

Two ways to comply with air barrier requirements:

- ✓ Materials – C402.5.1.2.1 OR
- ✓ Assemblies – C402.5.1.2.2



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Air Barrier Materials (C402.5.1.2.1)

1. Plywood not less than 3/8”
2. OSB not less than 3/8”
3. Extruded polystyrene insulation board not less than ½”
4. Foil-backed polyiso insulation board not less than ½”
5. Closed-cell spray foam with a minimum density of 1.5 pcf not less than 1.5” thickness
6. Open-cell spray foam with a density of between 0.4 and 1.5 pcf not less than 4.5” thickness
7. Gypsum board not less than ½”
8. Cement board not less than ½”
9. Built-up roofing membrane
10. Modified bituminous membrane
11. Fully adhered single-ply membrane
12. A cement/sand parge or gypsum plaster not less than 5/8”
13. Cast-in-place and precast concrete
14. Fully grouted concrete block masonry
15. Sheet steel or aluminum
16. Solid or hollow masonry constructed of clay or shale masonry units

72

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Envelope [C402.5.1.1(3)]

Air sealing

New text in the 2018 IECC:

Sealing shall allow for expansion, contraction and mechanical vibration.



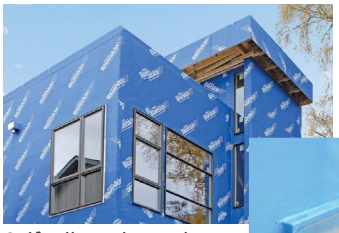
Photo Courtesy of Matt Risinger & https://www.greenbuildingadvisor.com/article/urban-rustic-air-sealing-the-exterior-sheathing

73

Envelope [C402.5.1.1]

Air sealing

Lots of methods available for air sealing


Self adhered membrane


Fluid applied membrane


Housewrap

Pay attention to complex/hidden details & joints

https://www.buildingscience.com/documents/insights/bsi-084-forty-years-of-air-barriers

74

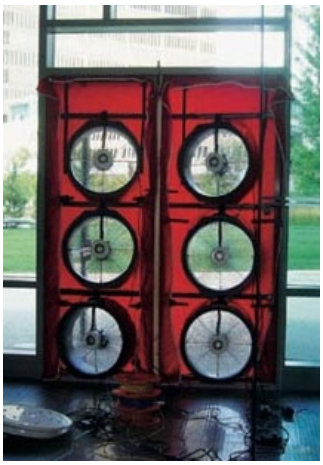
Blower door testing

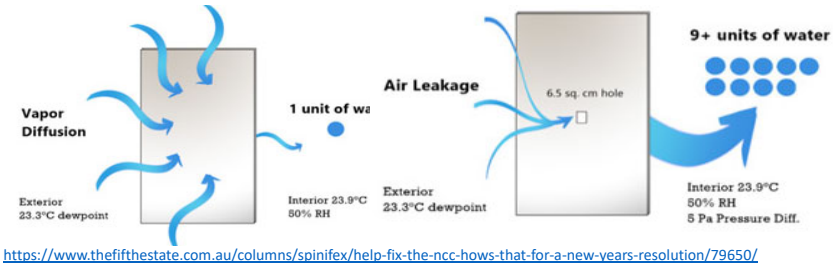
Not required for commercial, mandatory for residential construction

Residential air leakage not to exceed 4 air changes per hour @ 50 Pa

Commercial leakage not to exceed 0.4cfm/sf of envelope area @ 75 Pa

Testing performed after creation of all penetrations of the building thermal envelope





https://www.thefifthestate.com.au/columns/spinifex/help-fix-the-ncc-hows-that-for-a-new-years-resolution/79650/

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IBC Chapter 14 (2018)

1404.3 Material vapor retarder class

1. Class I: perm rating of less than or equal to 0.1 (Polyethylene sheeting (4 mil min))

   (Vapor impermeable)

2. Class II: perm rating greater than 0.1 and less than or equal to 1.0 (Kraft-faced fiberglass batts)

   (Vapor semi-impermeable)

3. Class III: perm rating of greater than 1.0 and less than or equal to 10.0 (latex or enamel paint)

   (Vapor semi-permeable)

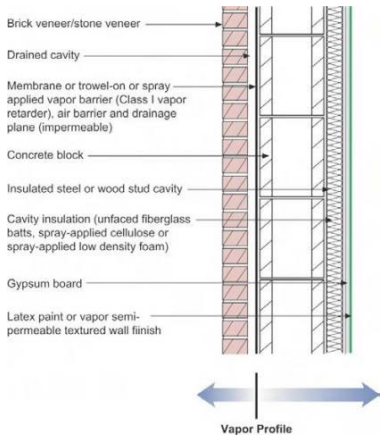

Image courtesy of Pacific Northwest National Labs

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Envelope [C402.5.2]

Door Types

New to the 2018 IECC:

Adds power operating sliding or folding doors to the Maximum Air Leakage Rate for Fenestration Table

Table C402.5.2 (excerpt)
MAXIMUM AIR LEAKAGE RATE FOR FENESTRATION ASSEMBLIES

FENESTRATION ASSEMBLY	MAXIMUM RATE (CFM/SF²)
Curtain walls	0.06
Storefront glazing	0.06
Commercial glazed swinging entrance doors	1.00
Power-operated sliding doors and power-operated folding doors	**1.00**
Revolving doors	1.00

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Envelope [C402.5.6]

Loading Dock Weatherseals

New text in 2018 IECC:

Cargo door openings and loading door openings shall be equipped with weatherseals that restrict infiltration and provide direct contact along the top and sides of vehicles that are parked in the doorway

Photo Courtesy of US DOE

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Section C403 & C404 Mechanical Systems & Service Water Heating

Systems [C403]

Chicago Changes to Systems Requirements

All changes to C403 Systems section simplify to Climate Zone 5A.

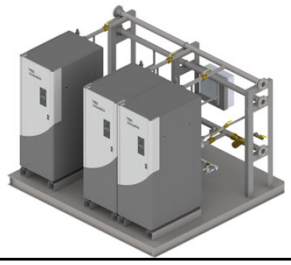
1. C403.4.3.3.2 “The following shall apply to hydronic water loop heat pump systems ~~in Climate Zones 3 through 8:”~~
2. C403.4.4 Item 3.2 - Where pumps have automatic direct digital control configured to operate pumps only when zone conditioning is required, a VSD shall be provided for motors greater than 7.5hp or greater.
3. Delete Table C403.4.4 – VSD requirements for demand-controlled pumps
4. Delete Climate Zone-specific exceptions in section C403.5
5. Simplify Table C403.5(1) to Climate Zone 5A
6. Delete Table C403.5(2) – Equipment Efficiency Performance Exception for Economizers
7. Delete Climate Zone-specific exceptions in section C403.7.4

Systems [C403.3.1]

Equipment Sizing

The output capacity of heating and cooling equipment shall not be greater than that of the smallest available equipment size that exceeds the loads calculated in accordance with Section C403.1.1.

- Code allows for installation of stand-by equipment (N+1)
- Code allows for multiple units exceeding capacity provided controls limit operation of units based on load.
  - Modular systems are a good example of this compliance method, providing redundancy and built-in staging control.



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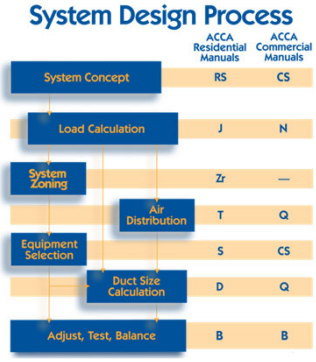
Systems [C403.3.1]

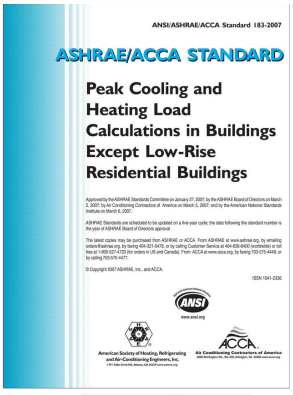
How to Size Equipment?

Over-sizing issues
- Unnecessary increased capital costs
- Continual low part-load can reduce equipment life and efficiency

Under-sizing issues
- Unmet loads and comfort issues



Right-size using load calculation software or sheets
- ASHRAE/ANSI/ACCA Standard 183
- ACCA manuals at left
- eQuest/Energy Plus/Trane Trace/Carrier HAP and others



eQUEST

TRACE 700

EnergyPlus

HAP HOURLY ANALYSIS PROGRAM

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Systems [C403.3.2]

System Efficiency Updates in 2018 IECC

- Table C403.3.2(3) Room air conditioner minimum efficiency unit changed from EER to CEER (Combined EER)
  - Accounts for stand-by energy consumption, not just operation when the unit is actively cooling.
- Table 403.2.3(4) Gas- & oil-fired furnace minimum efficiency increased from 78% to 80% AFUE (gas) and 83% AFUE (oil).
- Table 403.2.3(5) Gas- & oil-fired boilers added two footnotes:
  - f. forbids constant-burning pilots
  - g. requires temperature resets for boilers without tankless domestic water heating.

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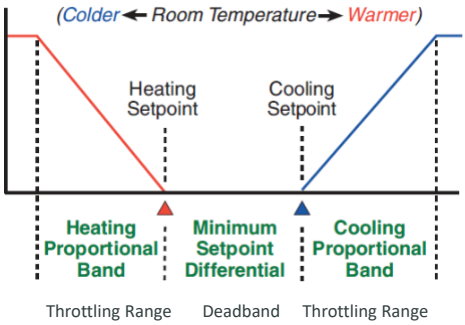
Systems [C403.4]

Heating and Cooling System Controls

- Almost all controls are existing from 2015 IECC, but have been clarified as mandatory and have requirement to be configured rather than just capable.
- C403.4.1 Zone thermostatic controls
  - Heat pump supplemental heat limitation
  - Thermostat dead-band
  - Hot water resets
- C403.4.2 Unoccupied Controls
- C403.4.3 Heat Pump Controls
- C403.4.4 Part Load Controls (HW/CHW resets)
- C403.4.5 Pump Isolation



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Systems-Economizers [C403.5]

Economizer Fault Detection and Diagnostics

Air-cooled unitary DX units listed in Tables C403.3.2(1) – (3) and VRF units that are equipped with an economizer in accordance with C403.5-C403.5.4 shall include a fault detection and diagnostics system…

- Monitor supply, return, and outside air temperatures
- Provide status on key system operations
- Report air temperature sensor faults, improper economizing, damper malfunctions, and excess OA flow.
- Failed economizers can dramatically increase energy consumption for heating/cooling.

Image source: Honeywell

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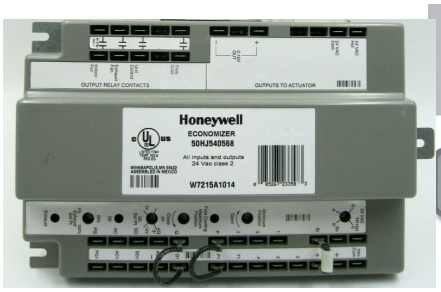
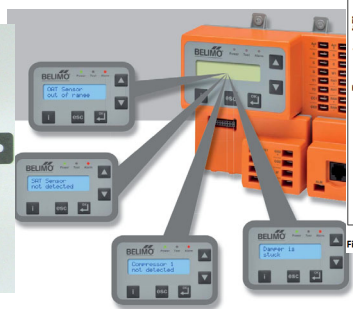
Systems-Economizers [C403.5]

Example Economizers/Trend Analysis

Common economizer controller for RTUs bottom left.

- Common errors include incorrect settings on controller, which is hard to read.
- Modern controllers have LCDs showing settings/set points to reduce setting errors in programming (center).
- Typically errors not found until RCx reviews trend logs





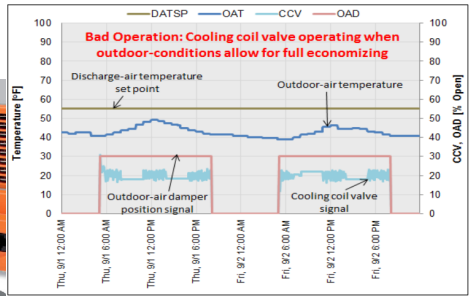


Figure 7: Cooling coil valve opening when outdoor conditions allow for full economizing, wasting cooling energy.

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Ventilation and Exhaust Systems [C403.7.1]

Demand Control Ventilation

DCV shall be provided for spaces larger than 500 sf and with an average occupant load of 25 people or greater per 1,000 sf of floor area…and served by systems with (1.) air-side economizer, (2.) automatic modulating control of OA damper, and/or (3.) design OA of >3,000cfm.

- Exceptions:

1. Systems with energy recovery complying with C403.7.4
2. Multiple-zone systems without DDC of individual zones communicating with a central control panel
3. Systems with a design outdoor airflow less than 1,200 cfm
4. Spaces where the supply flow rate minus any make-up or outgoing transfer air requirements is less than 1,200 cfm
5. Ventilation provided only for process loads.

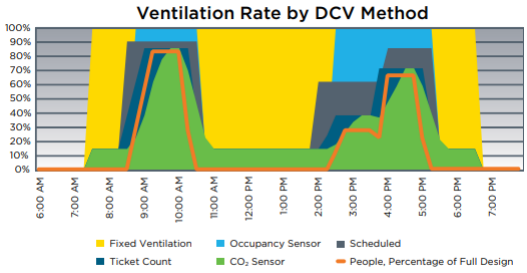


Figure 1. Ventilation rates provided with fixed ventilation and DCV alternatives

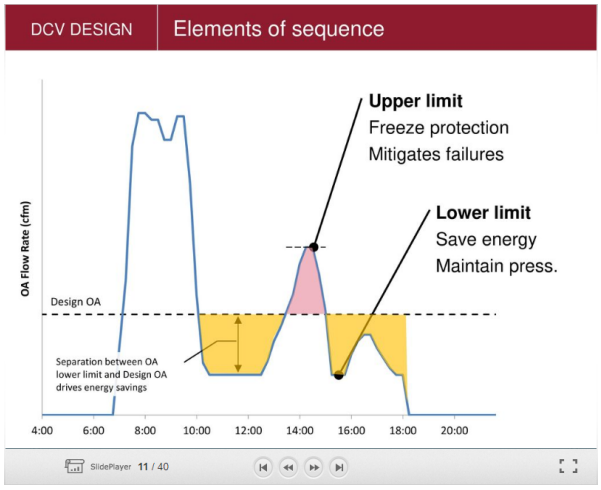
Chart courtesy Energycodes.gov: Note that all methods of DCV reduce airflow over a fixed ventilation rate.

Ventilation and Exhaust Systems [C403.7.1]

Common DCV Issues

Common issues:

- Economizer not set-up to override DCV, resulting in loss of economizing ability
- Confusion on CO_2 sensor set points (too low/high) depending on set point type (differential or total CO_2)
  - Ventilation control based on differential CO_2 of 700ppm above *ambient*
  - Ambient generally varies from ~400-450ppm depending on location, though heavy urban can be as high at 900ppm
- Minimum area ventilation and maximum occupant ventilation limits are not set at the AHUs controls, resulting in incorrect ventilation levels.



DCV presentation MN Energy Expo, Scott Hackel, Senior Energy Engineer

Ventilation and Exhaust Systems [C403.7.1]

Enclosed Parking Structures

- C403.7.2 – Enclosed parking garages…shall employ contamination-sensing devices and automatic controls configured to stage fans or modulate average flow rates to 50% or less of design capacity, or intermittently operate fans <20% of the occupied time as required…in accordance with IMC provisions.
- IMC 404.1 – Intermittent fan operation controlled by CO *and* NO_2 detectors.
- IMC 404.2 – Airflow minimum shall be ≥0.05cfm/sf and capable of producing 0.75cfm/sf.

Fans should never be fully off, per the IMC!

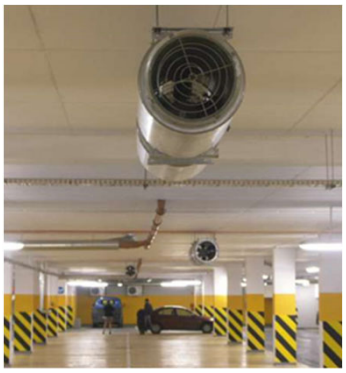


Image courtesy www.parking-net.com

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Systems-Energy Recovery [C403.7.4]

Energy Recovery Ventilation Systems

Where the supply airflow rate of a fan system exceeds the values specified in Tables C403.7.4(1) and C403.76.4(2), the system shall include an energy recovery system.

Table C403.7.4(1) and (2) CZ 4A and 5A

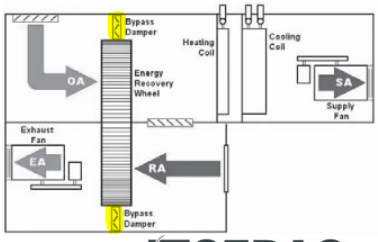
Operation	Percent (%) Outside Air at Full Design Airflow Rate (CZ 4A and 5A)							
	≥10% <20%	≥20% <30%	≥30% <40%	≥40% <50%	≥50% <60%	≥60% <70%	≥70% <80%	≥80%
<8,000 hr/yr	≥26,000	≥16,000	≥5,500	≥4,500	≥3,500	≥2,000	≥1,000	≥120
>8,000 hr/yr	≥200	≥130	≥200	≥200	≥200	≥200	≥200	≥200

ERV must recover 50% of enthalpy difference between outside and return air streams at design conditions.

ERVs need to have bypass or controls to allow economizer operation as per C403.5

- Bypass can be VFD on wheel that stops rotation, or bypass dampers

Annual energy reduction potential of 25%-50%



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Systems-
Guest Rooms
[C403.7.6]

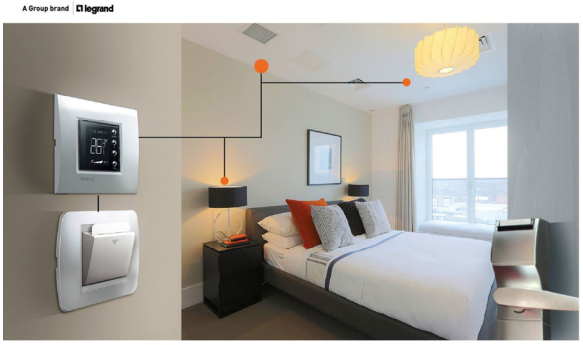
Guest Room Controls

New mandatory provisions in 2018 IECC
C403.7.6.1

- Raise cooling and lower heating setpoint 4F within 30min after occupants leave room.
- Raise cooling to 80F and lower heating to 60F when guest room is:
  - Unrented
  - has not been occupied for more than 16hrs.
  - A networked room shows unoccupied for more than 30 min
- Allowances made for pre-conditioning 1hr ahead of occupancy and humidity control.

C403.7.6.2

- Controls provided on HVAC systems capable and configured to turn off or isolate room ventilation & exhaust within 30min of unoccupancy
- Allowance for 1hr pre-occupancy purge cycle.



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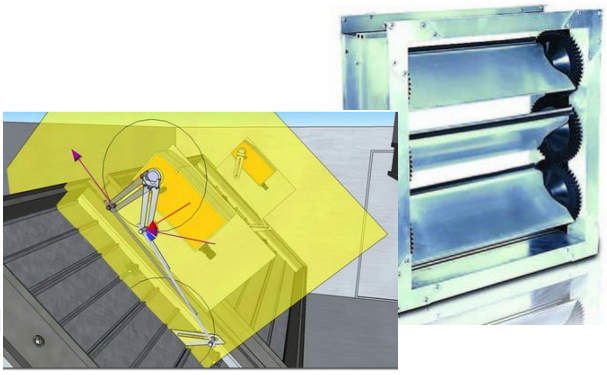
Systems - Shut-off
Dampers
[C403.7.7]

Shut-off Dampers

Outdoor air intake and exhaust openings and stairway and shaft vents shall be provided with Class 1 motorized dampers [with] an air leakage rate of ≤4cfm/sf of damper surface area at 1" w.g. and shall be labeled by an approved agency when tested in accordance with AMCA 500D for this purpose.

- Low-rise buildings can have gravity dampers with leakage rates <20cfm/sf if >24" in either dimension or <40 cfm/sf if <24" in either dimension
- Common problem that linkage geometry is incorrect to maintain closure seal or provide full range of motion.
- Some RTUs only have gravity closure dampers, which don't always stay sealed on a pressurized RTU plenum or in breeze.



Economizers–The Physics of Linkage Systems-David Sellers, Facility Dynamics Engineering

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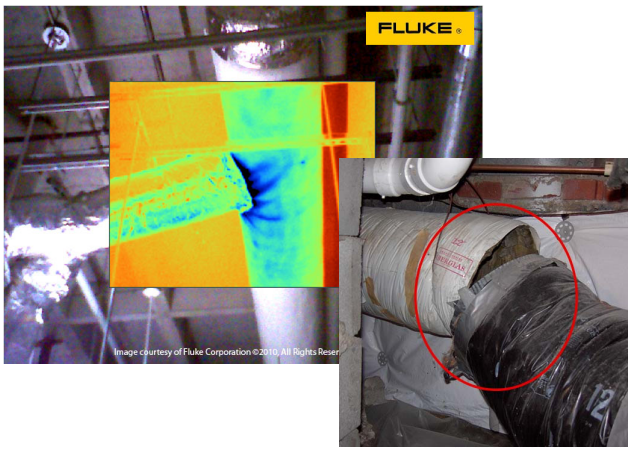
Systems
Ducts
[C403.11.1]

Duct and Plenum Insulation and Sealing

Supply and return dusts and plenums shall be insulated with not less than R-6 insulation where located in unconditioned spaces and where located outside the building with not less than…R-12 insulation…Ducts, air handlers and filter boxes shall be sealed.

- Residential testing commonplace, not for commercial, though.
- Particularly bad for open returns – enhance supply leaks and building infiltration.
- Duct joints often covered or improperly seal to insulation rather than duct-to-duct.
- DO NOT USE DUCT TAPE!

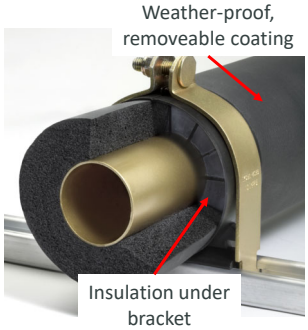


Systems
Pipe Insulation
[C403.11.3.1]

Protection of Piping Insulation

Piping insulation exposed to the weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted.

- Commonly an issue with small refrigeration units (residential-style DX, small diameter pipes)
  - Wrapped with foam pipe wrap, and nothing else
  - UV-degradation turns insulation to dust after a few years
  - Crimped by zip-ties
  - Gaps/incomplete insulation



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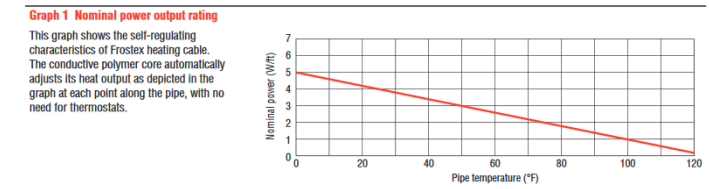
Service Water Heating [C404.6 & C404.7]

Freeze Protection System Controls

Freeze protection systems, such as heat tracing or outdoor piping and heat exchangers… shall include automatic controls configured to shut off the systems when outdoor air temperatures are >40 °F or when the conditions of the protected fluid will prevent freezing.

- Common for heat-trace to be active year-round
- Common issues:
  - Freeze protection pumps running continuously
  - Dry-bulb used for cooling tower fill protection – should be wet bulb



Source: Frostex® freeze protection system

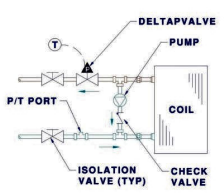
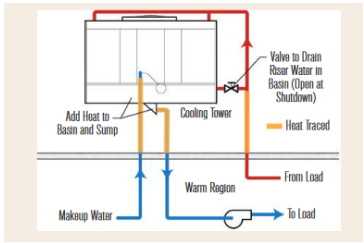


Figure 10: Pumped Coil Schematic
Pump 25% of coil design flow for freeze protection.



COURTESY OF SPX COOLING TECHNOLOGIES

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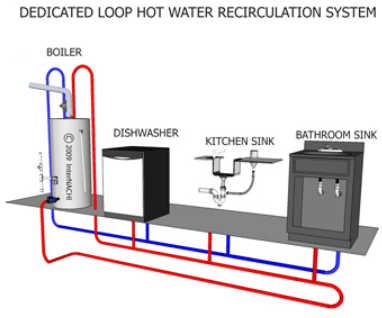
Service Water Heating [C404.6 & C404.7]

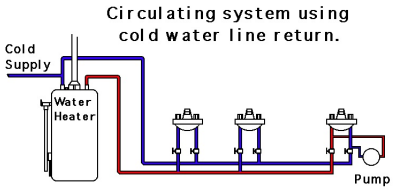
Circulation Systems & Demand Recirculation

C404.6.1: Controls shall start the pump based on the identification of a demand. The controls shall automatically turn off the pump when the loop is at the desired temperature and there is no demand for hot water.

C404.7: The controls shall start the pump on a demand for hot water. The controls shall limit the temperature of the water entering the cold-water return piping to ≤ 104 °F.



https://www.nachi.org/hot-water-recirculation-systems.htm



http://hotwaterrecirculatingpump.com/

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Service Water Heating [C408]

System Commissioning

- 2018 IECC controls shall be ***configured*** with as noted in previous slides:
- C408.2.1 requires a commissioning plan
- C408.2.3 requires functional testing of systems to confirm configuration of C403.4 HVAC Controls and C405.2 Lighting Controls
- C408.2.4 Preliminary commissioning report must be submitted to owner, and reviewed by code official
  - Denote deficiencies, deferred testing, test results, and test procedures.

Commissioning often cut from construction budgets as other line-items exceed projected costs, or delays occur.

LBL report found that commissioning new construction reduced energy $0.18/sf-yr at a cost of $1.16/sf

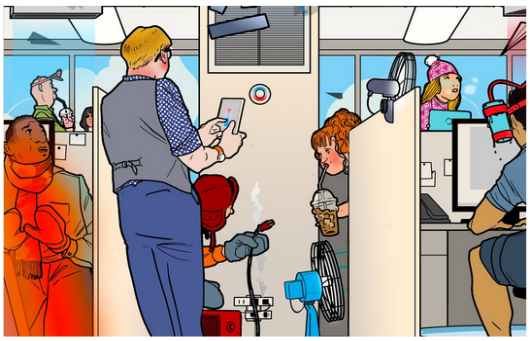

ILLUSTRATION: JASON SCHNEIDER WSJ - Let the Thermostat Wars Begin

Section C405 Lighting and Electrical Systems

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Lighting Systems
General
[C405]

Chicago Amendment to Dwelling Unit Lighting

- C405.1 General
  - No less than 90% of permanently installed lighting in *dwelling units* shall be provided by lamps with an efficacy ≥65lm/W or fixtures with efficacy ≥55lm/W or comply with C405.2.4 & C405.3
  - Narrows definition of high-efficacy lighting and simplifies reference from multiple criteria to simple lm/W requirement.
- C405.2 Lighting Controls – 2015 to 2018 IECC update
  - Delay time for occupancy sensors reduced from 30min to 20min

Lighting Controls
Occupant Sensors
C405.2.1

Occupant Sensor Controls are Required in

1. Classrooms/lecture/training rooms
2. Conference/meeting/multi-purpose rooms
3. Copy/print rooms
4. Lounges/breakrooms
5. Enclosed offices
6. **Open plan office areas** New to 2018 IECC
7. Restrooms
8. Storage rooms
9. Locker rooms
10. Other spaces 300 sf or less enclose by floor-to-ceiling height partitions
11. **Warehouse storage areas**

Lighting Controls
Occupant Sensors
C405.2.1.2

Warehouse

- Must reduce lighting power by at least 50% when unoccupied.
- Controls must cover aisleways and open areas.
- Control for each aisle way shall be independent and shall not control beyond the aisle way.

Image from http://luxreview.com

Lighting Controls
Occupant Sensors
C405.2.1.3

Occupant Sensors in *Open Plan Offices (≥ 300 sf)*

1. Control zones limited to 600 sf
2. Must reduce lighting power by at least **80%** in a reasonably uniform pattern within 20 minutes after no occupancy
3. Turn off general lights in all zones within **20 minutes** of occupants leaving
4. Daylight responsive controls may activate fixtures only if occupants present

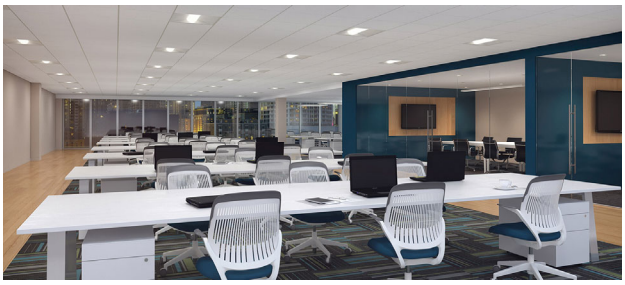

Image from https://www.focalpointlights.com

Lighting Controls
Occupant Sensors
C405.2.1.1

Occupant Sensors in *Other Areas*

1. Auto-off within **20 minutes** of occupants leaving.
2. Manual on; or auto-on if not more than 50% power.
   - Exception: Full auto-on permitted in public corridors, stairways, restrooms, primary building entrance areas and lobbies, and areas where manual-on operation would endanger the safety or security of the room or occupants.
3. Shall incorporate manual control to allow occupants to turn lights off.

Image from https://lightingcontrolsassociation.org

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Lighting Controls
Time Switch
C405.2.2

Time-switch Controls are Required at

- Areas not provided with occupant sensor controls need time-switch
- Exception:
  Areas with manual control (C405.2.2.2) where
  1. Patient care is directly provided
  2. Automatic shutoff would endanger occupant safety or security
  3. Lighting intended for continuous operation
  4. Shop and laboratory classrooms

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Lighting Controls
Time Switch
C405.2.2.1

Time-switch Control Functions

- Each space with time-switch controls shall be provided with a manual control for light reduction in accordance with C405.2.2.2.
- Time-switch controls shall comply with following:
  1. Minimum 7-day clock
  2. Capable of 7 different day types
  3. Holiday shut-off (skip schedule for 24 hrs)
  4. Program backup of at least 10 hours
  5. Include override switch (manual, max. 2hrs & individual override switch shall not cover larger than 5,000 sf)

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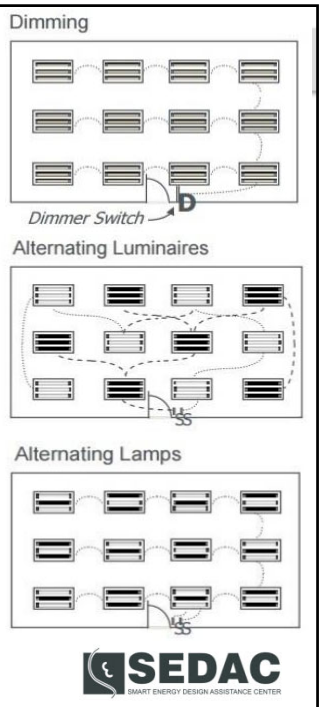
Lighting Controls
Light Reduction
C405.2.2.2

Light-reduction Controls

1. Manual controls to allow occupants to reduce ligh least 50% in reasonably uniform pattern
   1. Control all lamps/luminaires
   2. Switching alternate rows or luminaires
   3. Switching outer lamps
   4. Switching each lamp/luminaire
2. Exceptions for:
   1. Spaces with 1 luminaire rated less than 100 w
   2. Spaces <0.6 watts/SF
   3. Corridors, lobbies, electrical / mechanical roon
   4. Daylight zones with daylight responsive contro



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Lighting Controls
Time Switch
C405.2.2.3

C405.2.3 Daylight Controls

•Required in the following spaces:

1. > 150 W of general lighting in sidelit zone
2. > 150 W of general lighting in toplit zone

•Exceptions:

•1. Health care facilities where patient care is directly provided

•2. Lighting required for specific application control per C405.2.4

- 3. Sidelit zones on 1st floor above grade in Group A-2 (assembly uses for food/drink) and Group M (mercantile) occupancies

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Daylighting Control Exception #4

Connected lighting power < Adjusted lighting power budget

Adjusted lighting power budget = Normal lighting power budget * (1.0- [0.4* ratio of daylight area to total lit floor area])

If below this threshold, no daylight controls required

Example Office:

200,000 sf total area
50,000 sf daylit zones
LPD: 0.79 W/sf
LPA: 158,000 W

LPA adj
= 158,000 W x (1.0 – 0.4x50,000/200,000)
= 158,000 W x 0.9
= 142,200 W (10% less)

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C406.3 Reduced Lighting Power Option

- To follow prescriptive compliance path, you need to comply with at least one of the Additional Energy Efficiency Options
- Total connected power shall be **< 90%** of total lighting power allowance per C405.3.2
- Often pairs well with daylight control Exception #4

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C405.2.3.1 Daylight Control Functions

1. Toplit and sidelit separately controlled (up to 150W overlap acceptable)
2. Must be able to be calibrated within the space
3. Calibration mechanism must be readily accessible
4. Must dim continuous down to at least 15% in offices, classrooms, laboratories, and library reading rooms
5. Must be configured to turn lights completely off when adequate daylight present
6. Sidelit zones of different cardinal directions controlled independently
   Exception: < 150 W in each space can be controlled together.

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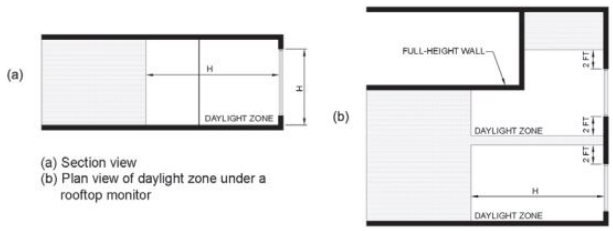
C405.2.3.2 Daylit Zones

Sidelit Zones

- Floor area adjacent to vertical fenestration
- Area of fenestration ≥ 24 sf
- Visible Transmittance ≥ 0.20

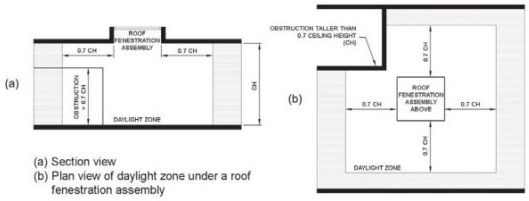
Daylit Zones

- Floor area underneath a roof fenestration
- No buildings block direct sunlight
- (VT x area of roof opening) / toplit zone area ≥ 0.008



(a) Section view
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.3.2
SIDELIT ZONE



(a) Section view
(b) Plan view of daylight zone under a roof fenestration assembly

FIGURE C405.2.3.3(1)
TOPLIT ZONE

Lighting Controls
Specific Applicaitons
C405.2.2.4

Specific Application Controls

(Occupancy sensor or Time-switch) + Manual control required in:

- Display and Accent area
- Lighting in display cases
- Supplemental task lighting
- Lighting for sale or demonstration

Sleeping Units

- Automatically switch off all permanent luminaires & switched receptacles within 20 min. after no occupancy
- Exceptions: Keycard controlled & patient care spaces

Dwelling Units

- Permanent lighting controlled with light reducing or occupancy controls

Non-visual applications

- Plant growth, food warming, etc…controlled with time switches

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Luminaire Level Lighting Control (LLLC)

C405.2 Lighting Control
(Choose one)

Lighting Controls	LLLC
C405.2.1	C405.2.1
C405.2.2	C405.2.4
C405.2.3	C405.2.5
C405.2.4	
C405.2.5	
C405.2.6	

LLLC shall independently capable of:

Monitoring occupancy to brighten or dim lighting

Monitoring electric & daylight to brighten or dim electric lights

Configuration & reconfiguration of performance parameters (dim setpoints, timeouts, wireless zoning…)

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Lighting Controls
Exterior Lighting
C405.2.2.6

Exterior Lighting Controls

C405.2.6 Exterior Lighting Control

Exterior Lighting	Decorative Lighting
C405.2.6.1	C405.2.6.1
	C405.2.6.2
C405.2.6.3	
C405.2.6.4	C405.2.6.4

Façade & Landscape Lighting

C405.2.6.1:
Daylight Shutoff

C405.2.6.2:
Decorative Lighting Shutoff

C405.2.6.3:
Lighting Setback

C405.2.6.4:
Time-switch Function

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Lighting Controls
Exterior Lighting
C405.2.2.6

Exterior Lighting Controls

- Daylight Shutoff
- Decorative Lighting Shutoff
- Lighting shall automatically shutoff ≤1 hr after closing to ≤1 hr before opening
- Lighting Setback
- Total wattage reduced by ≥ 30% by switching or dimming during one of the following:
  - From not later than midnight to not earlier than 6 am
  - From ≤ 1 hour after business closing to ≤ 1 hour before opening
  - During any time where activity has not been detected for ≥ 15 min
- Time-switch Control
  - Same as interior time-switch

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Lighting Controls
Total Power
C405.3.1

Total Connected Interior Lighting Power

Factors included in connected lighting power

- Rated lamp wattage of line-voltage fixtures
- Ballast input wattage
- Transformer input wattage
- Track lighting
  - 2018 IECC: **8W/ft** (2015 IECC was 30 W/ft)
  - AHRAE 90.1-2016: 30 W/ft
  - NEC: 150W/2ft

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Table C405.3.2 (1) Interior LP Allowances: Bldg Area Method

Bldg Area Type	2015 IECC (W/SF)	2018 IECC (W/SF)	% Improvement
Automotive facility	0.80	0.71	11%
Convention Center	1.01	0.76	25%
Courthouse	1.01	0.90	11%
Dining: Bar lounge/leisure	1.01	0.90	11%
Dining: cafeteria/fast food	0.90	0.79	12%
Library	1.19	0.78	34%
Dormitory	0.57	**0.61**	**-7%**
Performing Arts Center	1.39	1.18	15%

Major reductions primarily due to LED technology advancements

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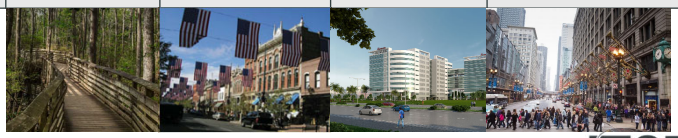
C405.4.2 Exterior Lighting Power Allowance

Table C405.4.2(1) partial

Exterior Allowance	Zone 1	Zone 2	Zone 3	Zone 4
Base allowance	350	400	500	900 W
Parking/drives	0.03	0.04	0.06	0.08 W / sf
Walkways <10' wide	0.5	0.5	0.6	0.7 W / lf
Walkways, other	0.1	0.1	0.11	0.14 W / sf
Landscaping	0.03	0.04	0.04	0.04 W / sf
Entry canopies	0.2	0.25	0.4	0.4 W / sf



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C405.4.2 Exterior Lighting Power Allowance

Table C405.4.2(2) & (3) partial

Type (Zone 3)	2015 IECC (W/sf)	2018 IECC (W/sf)	% Improvement
Parking Area	0.10	0.04	60%
Stairways	1.00	0.70	30%
Entry Canopies	0.40	0.40	0%
Loading Dock	0.50	0.35	30%
Sales Canopies	0.80	0.60	25%
Non-tradable			
Entry parking 24/7	800 W	400 W	50%
Drive-up	400 W	200 W	50%

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Section R402-R404 Residential

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Residential Envelope [R402]

Chicago Amendments to Residential

Multiple changes made to residential requirements by Chicago Amendments

1. R402.1.1 adds note about vapor retarder, referencing Section 1405.3 of the *Chicago Building Code*
2. R402.1.2 deletes other Climate Zones
3. R402.1.4 deletes other Climate Zones
4. R402.2.1 modifies attic ceiling insulation description to refer only to Climate Zone 5A requirements.
5. R402.2.2 modifies low-slope roof insulation description to refer only to Climate Zone 5A requirements.
6. Removes exception for termite-infested areas not requiring perimeter slab insulation.

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Residential Envelope [R402]

Chicago Amendments to Residential

Changes continued

7. Deletes IRC reference from crawl space vapor-retarder reference
8. Modifies R402.2.13 Exception #1 to refer only to Climate Zone 5A
9. Modifies R402.3.5 to refer only to Climate Zone 5A
10. Modifies R402.4.1.1 by removing option for cod official to require insulation inspections
11. Revises R402.4.1.2 changes air leakage requirement from 3ACH to 4ACH and removes requirements for other Climate Zones
12. Add exceptions to air leakage testing to R402.4.1.2
13. R402.4.4 removes references to other Climate Zones
14. R402.5 simplified to Climate Zone 5A

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Residential Envelope [R402.1]

R402.1.2 Insulation and Fenestration Criteria

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b,e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.32	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	~~15/19~~10/13	10, 2 ft	15/19
6	0.30	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Note the highlighted change is an IL amendment

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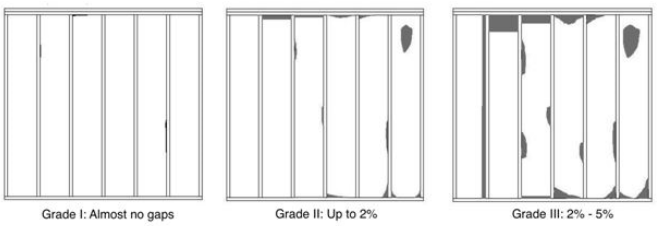
HERS Grades of Insulation Installation

- **Grade I** is the best. This means that the insulation is installed according to the manufacturer's instructions. It completely fills the cavity in the case of air-permeable insulation is also is encapsulated on six sides. It's cut around electrical junction boxes, split around wires and pipes, and generally not compressed. Modeled at 100% insulated in rating software.
- **Grade II** is second best. There's some allowance for imperfections in the installation but overall is done well. The HERS Standards say a Grade II installation can have "moderate to frequent installation defects: gaps around wiring, electrical outlets, plumbing and other intrusions; rounded edges or "shoulders"; or incomplete fill..." Modeled at 98% insulated.
- **Grade III** is the lowest grade. It has "substantial gaps and voids." Modeled at 95% complete.



RESNET protocol for the effect of missing insulation on installation grade
Diagrams from the HERS Standards

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Insulation Critical Details

Residential Envelope [R402.2.9]

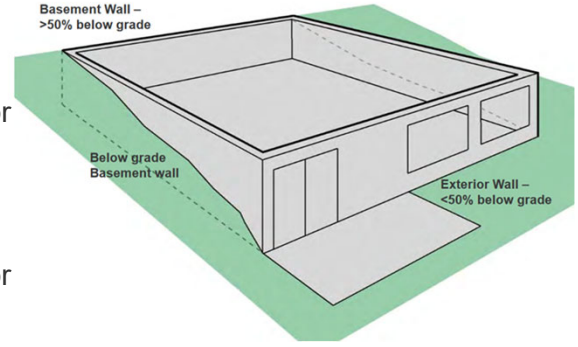
R402.2.9 Basement Walls

IECC Definition of a *Basement Wall*:
A wall 50 percent or more below grade and enclosing *conditioned space.*

Basement wall insulation requirements:
IL: 10/13

10ft depth option: 10/13 means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation on the interior of the basement wall.

4ft depth option: 15/19 means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation on the interior of the basement wall. Alternatively, compliance with "15/19" shall be R-13 cavity insulation on the interior of the basement walls plus R-5 continuous insulation on the interior or exterior of the home.



Residential Envelope [R402.2.9]

Air Sealing – 2 Step Mandatory Requirement

R402.4.1.1 Installation

- The components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in the Table
- ~~Where required by the code official, an approved third party shall inspect all components and verify compliance~~

R402.4.1.2 Testing

The building shall be tested and verified as having an air leakage rate of 4 ACH_{50} in Illinois

Requirement of a written report

https://www.homeinnovation.com/~/media/Files/Reports/TechNotes-Building-Air-Tightness-January-2014.pdf

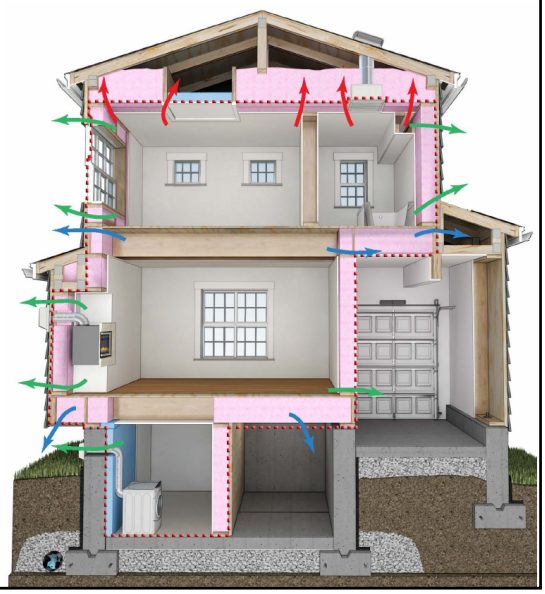
Ceiling Plane (vented attics)
- Top plates
- Access panel
- Penetrations – bath fans, duct boots, electrical
- Framed cavities – above kitchen cabinets, soffits, & chases

Walls [1c]
- Bottom plate at deck/slab
- Penetrations
- Sheathing
- Windows & doors
- Garage-side drywall
- Knee-wall air barriers
- Behind tubs & stairs
- Framed cavities – within chases & bulkheads

Fireplaces
- Behind pre-fabricated fireplaces
- Around dampers & vents

Rim Joist Areas
- Rim board – joist cavity
- Sill plate at foundation
- Draft stops at garage & knee walls

Floors
- Cantilevered
- Above garages, vented crawl spaces, & unconditioned basements



Is Air Sealing a Big Deal? ..... Yes!

Primary Energy Consumption attributed to building envelope components in 2010 (in quads) lead by infiltration!

Building Component	Residential	
	Heating	Cooling
Roofs	1.00	0.49
Walls	1.54	0.34
Foundation	1.17	-0.22
Infiltration	2.26	0.59
Windows (Conduction)	2.06	0.03
Windows (Solar Heat Gain)	-0.66	1.14

Source: Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies, DOE BTO, 2014
https://www.energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf

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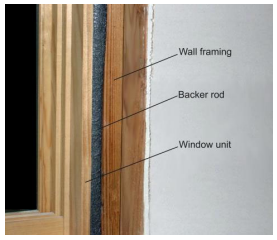
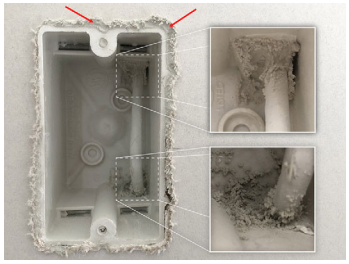
Examples of Air Sealing









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Residential Envelope Air Leakage [R402.4.1]

Blower Door Testing

- **Mandatory** for residential construction
- Residential air leakage rate not to exceed 4 air changes per hour @ 50 pascals
- Where required by code official, testing shall be conducted by an approved third party.
- Testing performed after creation of all penetrations of the building thermal envelope

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Bloor Door Testing Exceptions

By Chicago Amendment the following exceptions added to R402.4.1.2:

1. Additions, alterations, and repairs air tightness and insulation install considered acceptable based on Table R402.4.1.1 without testing
2. Heated attached or detached garage air tightness and insulation visually inspected to comply with R402.4.1.1 considered acceptable without testing – must be thermally isolated from rest of house
3. Multi-family building leakage procedures:

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3. Bloor Door Testing for Multifamily Housing

Low-rise multifamily

- Air leakage not exceeding 0.25 cubic feet per minute per square foot of enclosure area (all six sides) at 50 Pascal.
- Sampling methodology available for buildings >7 units – test 1 of every 7 units.

https://www.mncee.org/blog/may-2019/research-sidesteps-obstacles-measuring-air-tightne/

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Residential Systems
Ducts
[R403.3.1]

Duct Insulation (Prescriptive)

•Supply and return ducts in attics:

- Min. R-8 for ducts ≥ 3 inches. Min. R-6 for ducts < 3 inches in dia.

•Supply and return ducts in other areas:

- Min. R-6 for ducts ≥ 3 inches. Min. R-4.2 for ducts < 3 inches in dia.

•Exception: Ducts located completely inside the building thermal envelope

Location	Duct Dia ≥3" or <3"
Attic	R-8 or R-6
Conditioned Space	NR
Vented Crawlspace	R-6 or R-4.2
Conditioned Crawlspace	NR
Basement - Conditioned	NR
Basement - Unconditioned	R-6 or R-4.2
Exterior Walls	R-6 or R-4.2

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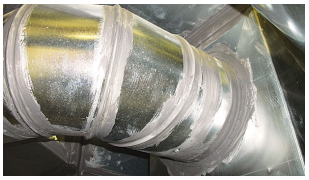
Residential Systems
Ducts
[R403.3.1]

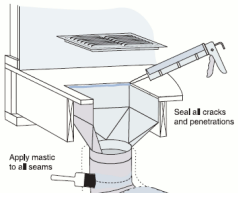
R403.3.2 Duct Sealing (Mandatory)

- Ducts, air handlers and filter boxes shall be sealed.
- Joints and seams shall comply with either the International Mechanical Code (IMC) or International Residential Code (IRC), as applicable.



- Why is duct sealing important?
- About 20 – 30% of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts.

https://www.energystar.gov/campaign/heating_cooling/duct_sealing



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R403.3.3 Duct Testing (Mandatory)

Ducts shall be pressure tested to determine air leakage by one of the following methods:

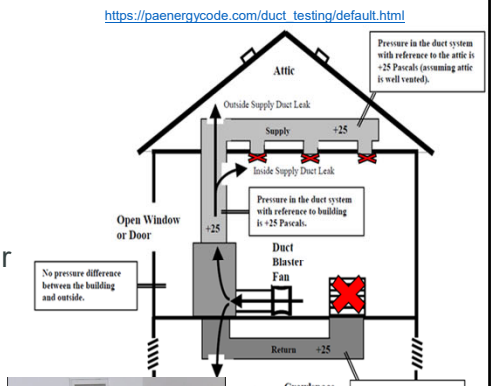
1. Rough-in test: Total leakage @ pressure differential of 0.1” w.g. (25 Pa) across the system, including the air handler enclosure if installed at the time. Registers shall be taped or otherwise sealed during the test.
2. Postconstruction test: Total leakage shall be measured @ 0.1” w.g. (25 Pa) across the system, including the air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exceptions

1. A test shall not be required where the systems are located entirely within the building thermal envelope.
2. A test shall not be required for ducts serving heat or energy recovery ventilators that are not integrated with ducts serving heating or cooling systems.

A written report of the results shall be signed testing party and provided to the Code Official.

https://paenergycode.com/duct_testing/default.html



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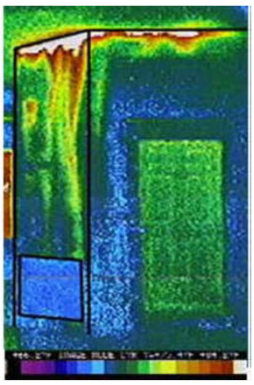
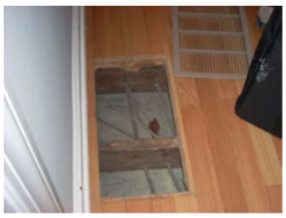
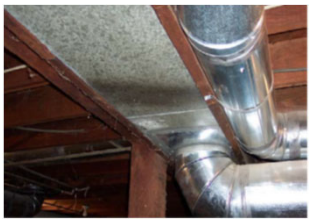
Old Practices Now Forbidden

R403.2.3 Building cavities (Mandatory).

Building framing cavities shall not be used as ducts or plenums.







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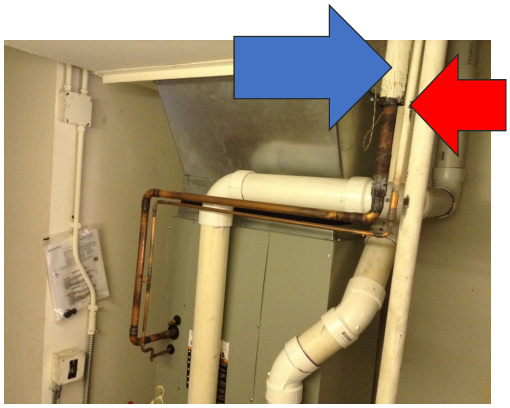
Residential Systems
Pipe Insulation
[R403.3.1]

Mechanical Piping Insulation (Mandatory)

- Mechanical system piping capable of carrying fluids greater than 105F or less than 55F shall be insulated to an R-value of not less than R-3
- Piping insulation exposed to weather shall be protected from damage including sunlight, moisture, equipment maintenance and wind. Adhesive tapes shall be prohibited.



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R403.5.3 Hot Water Pipe Insulation (Prescriptive)

Insulation for hot water piping with a thermal resistance , R-value, of not less than R-3 shall be applied to the following

1. Piping ¾ inch and larger in nominal diameter.
2. Piping serving more than one dwelling unit.
3. Piping located outside the conditioned space.
4. Piping from the water heater to a distribution manifold.
5. Piping located under a floor slab.
6. Buried piping.
7. Supply and return piping in recirculating systems other than demand recirculating systems.

https://basc.pnnl.gov/images/hot-water-heating-pipes-insulated-1-inch-jacketed-fiberglass

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Residential Systems
Ventilation
[R403.6]

Mechanical Ventilation

- Building to have ventilation meeting IRC or IMC or with other approved means
- Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating

- R403.6.1 Whole-house mechanical ventilation system fans to meet efficacy in Table R403.6.1
- Exception
  - When fans are integral to tested and listed HVAC equipment, powered by electronically commutated motor

Table R403.6.1
Whole-house mechanical ventilation system fan efficacy

Fan Location	Air flow rate (CFM)	Minimum Efficacy CFM/Watt)	Air Flow rate maximum (CFM)
HRV or ERV	Any	1.2 CFM/watt	Any
Range hoods	Any	2.8 CFM/watt	Any
in-line fan	Any	2.8 CFM/watt	Any
Bathroom, utility room	10	1.4 CFM/watt	<90
Bathroom, utility room	90	2.8 CFM/watt	Any

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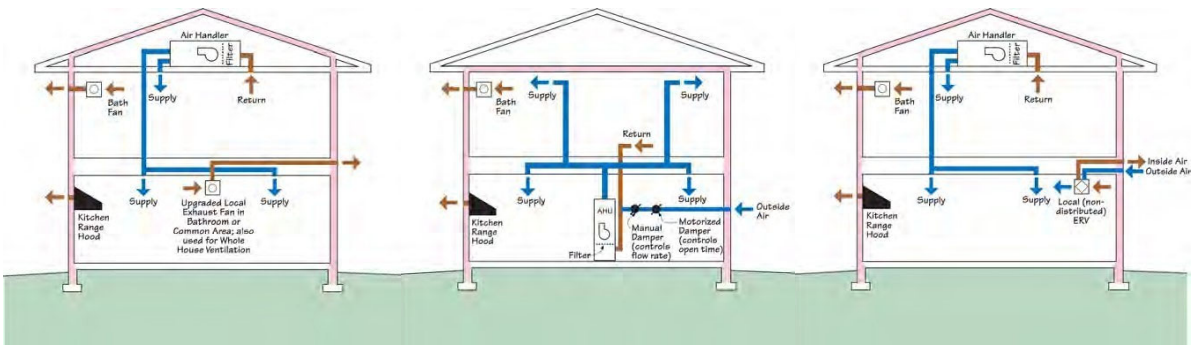
Ventilation Types (Negative, Positive, Balanced)

The 2018 IRC/IECC requires a continuously operating mechanical ventilation system to remove stale air and add fresh air to each dwelling. The required system flow rates are specified in Section M1507 of the 2015 IRC.
"Continuous operation" requires the system to either run at all times or cycle on at least once every four hours at a rate adequate to provide an overall average rate that meets the minimum flow requirement in the table.

Exhaust Only | Supply Only | Balanced



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Illinois Amendments Not Included in 2018 IECC

R403.6.2 Recirculation of air. (2018 IRC M1505.2)

R403.6.3 Exhaust equipment. (2018 IRC M1505.3)

R403.6.4 Whole-house mechanical ventilation system. (2018 IRC M1505.4)

- R403.6.4.1 System Design (2018 IRC M1505.4.1)
- R403.6.4.2 System Controls. (2018 IRC M1505.4.2)

R403.6.6 Mechanical Ventilation Rate. (2018 IRC M1505.4.3)

R403.6.4.3.1 Different Occupant Density.

R403.6.4.3.2 Airflow Measurement

R403.6.4.4 Local Exhaust Rates (2018 IRC M1505.4.4)

Illinois Amendments: https://www2.illinois.gov/cdb/business/codes/Pages/IllinoisEnergyConservationCode.aspx

Link to 2018 IRC: https://codes.iccsafe.org/content/IRC2018

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Residential Systems Sizing & Efficiency [R403.7]

Equipment Sizing & Efficiency Rating (Mandatory)

Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on *building* loads calculated in accordance with ACCA Manual J or other *approved* methodologies.

New or replacement heating and cooling equipment shall have an efficiency rating equal to or greater than the minimum required by federal law.

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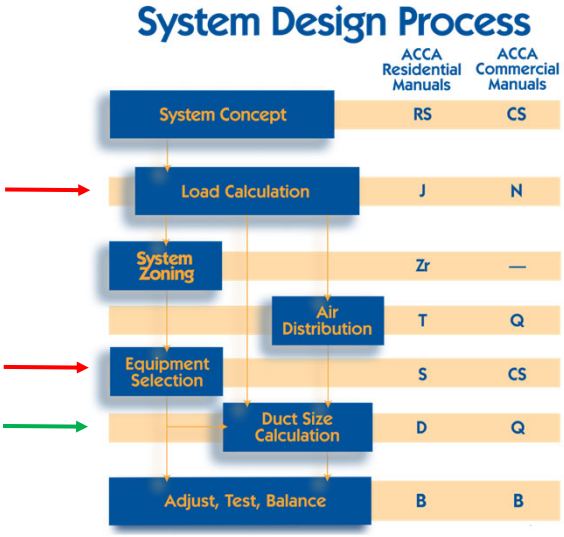
Mechanical System Design Process



https://www.acca.org/standards/technical-manuals

ACCA Technical manuals cover design, installation and maintenance for residential and light commercial HVAC systems.

HVAC Design Impacts
- 1st construction costs
- Comfort
- Indoor air quality
- Building durability
- Energy efficiency
- Higher customer satisfaction/ lower call backs

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Why the Emphasis on Sizing Equipment?

What has changed?

- Thermal envelopes have improved substantially
- Air tightness is now an important part of envelope construction
- Natural ventilation greatly reduced
- Rooms have much lower loads (Lighting)
- More moisture is retained

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Manual J Outdoor Design Conditions

Location	Elevation	Latitude	Winter	Summer					
	Feet	Degrees North	Heating 99% Dry Bulb	Cooling 1% Dry Bulb	Coincident Wet Bulb	Design Grains 55% RH	Design Grains 50% RH	Design Grains 45% RH	Daily Range (DR)
Pocatello AP	4454	43	0	90	60	-41	-34	-28	H
Twin Falls AP	4150	42	2	95	61	-44	-37	-31	H
Illinois									
Aurora	706	41	-1	91	76	42	49	55	M
Belleville, Scott AFB	453	38	10	93	77	46	53	59	M
Bloomington	875	40	-2	90	74	31	38	44	M
Carbondale	411	37	7	93	77	46	53	59	M
Champaign/Urbana	754	40	2	92	74	28	35	41	M
Chicago, Meigs Field	593	41	3	89	73	27	34	40	M
Chicago, Midway AP	620	41	0	91	73	24	31	37	M
Chicago, O'Hare AP	668	42	-1	88	73	29	36	42	M
Chicago CO	647	41	2	91	74	30	37	43	L
Danville	696	40	1	90	74	31	38	44	M
Decatur	682	39	3	91	75	36	43	49	M

https://farm-energy.extension.org/wp-content/uploads/2019/04/7.-Outdoor_Design_Conditions_508.pdf

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Manual S Equipment Selection Example

Equipment Selection using an ExampleChecklist

Design			Application Data: Equipment Capacity		
Winter Design Conditions			A furnace was selected for comparing "heating only" design and performance. Other types of equipment may be used.		
Outdoor °F:	27°F (A)	From Manual J8 Table 1A or 1B	Furnace Model Number:	FU600300	Fictitious furnace
Indoor °F:	70°F	Manual J8 §3-6 defaults to 70°F	Output BTUH:	52,000Btu/h (E)	Furnace Btu/h Output: (≤ 140% of calculated loss)
Total Calculated Heat Loss	50,981Btu/h (B)	Determined by Manual J8 load calculation			
Summer Design Conditions			A heat pump was selected for comparing cooling and heating design and performance. Other types of equipment may be used.		
Outdoor°F:	85°F (A)	From Manual J8 Table 1A or 1B			
Indoor °F:	75°F	Manual J8 §3-6 defaults to 75°F			
Entering Wet Bulb (EWB):	63°F (B)	Manual J8 §3-6 defaults to 63°F EWB (≈ 75°F / 50% RH)	Outdoor Unit Model Number:	HP-030 (F)	Fictitious heat pump

Total Heat Gain	27,543Btu/h (B)	Determined by Manual J8 load calculation (G)	Total Cooling Capacity (≤ 115%)	28,400Btu/h (F)	These capacities are from manufacturer's performance data at the DESIGN CONDITIONS: 85°F ODT, 1,000CFM, and 63°F EWB (G)	
Sensible Heat Gain	23,321Btu/h (G)		Sensible Cooling Capacity (≈ Sensible Gain)	21,600Btu/h (G)		
Latent Heat Gain	4,222Btu/h (G)		Latent Cooling Capacity (≈ Latent Gain)	6,800Btu/h (G)		
Sensible Heat Ratio (SHR)	85% (C)	See formula below	Indoor Unit Model Number:	AH-030	Fictitious air handler	
Design Air Flow	1,116 CFM (D)	The "TARGET" airflow we look for equipment that operates in this range (+/- 10%), on **medium** fan speed	Indoor Blower CFM (CFM in manufacturer's performance data at rated capacity-medium fan speed):	1,000 (D)	The actual equipment rated airflow, (medium fan speed optimal) should fall within target CFM,(+/- 15%)	
SHR = Sensible Heat / Total Heat Gain (C)		85 × 23,321Btu/h / 27,543Btu/h (D) = 85% ≈ 19° Design Temp	Btuh Difference between Heat Pump Balance Point and Total Heat Loss	30,281 Btu/h (H)	This heat pump can only produce 20,700Btu/h at design conditions. More capacity is required. (Air Conditioners do not have a balance point.)	
Sensible Heat Ratio versus Temperature Design Value		CFM = Sensible Heat Gain / Design Temp x 1.1	Auxiliary Heat (Circle): Electric Gas Oil	10 KW (H)	In this example the auxiliary heat is electric, the formula for electric heat is KW= Btu/h ÷ 3.413	
SHR	Recommended Temp. Design					
Below 0.80	21°F					
0.80 – 0.85	19°F	1,116 CFM = 23,321 Btu/h / 19 x 1.1				
Above 0.85	17°F					
From Manual J8 Tables		From Manual J8 Load Calculation		From Equip. Performance Data		

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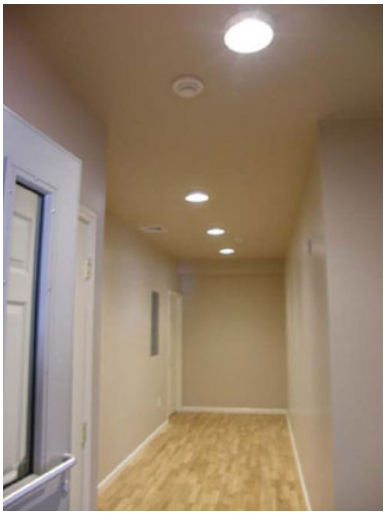
#39. R404.1, R402.4.5 Lighting (Mandatory)

Residential Lights [R404.1]

R404.1 Lighting Equipment (Mandatory)

- Illinois Amendments Definitions
- **High-Efficacy Lamps.** Compact fluorescent lamps, light-emitting diode (LED) lamps, T-8 or smaller diameter linear fluorescent lamps, or other lamps with an efficacy of not less than 65 lumens per watt or light fixtures of not less than 55 lumens per watt.
- Not less than 90 percent of the permanently installed fixtures shall contain only high-efficacy lamps
- Low voltage exception removed for 2018 IECC



Section C406 Additional Efficiency Package Options

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Section C406 Additional Efficiency Package Options

- C406.1 Requirements. Buildings shall comply with one or more of the following:
  1. Reduced lighting power
  2. Enhanced lighting controls
  3. On-site renewables
  4. More efficient HVAC
  5. Provision for dedicated outdoor air system
  6. High-efficiency service water heating
  7. The following two were added to 2018 IECC
  8. Enhanced envelope performance
  9. Reduced air infiltration

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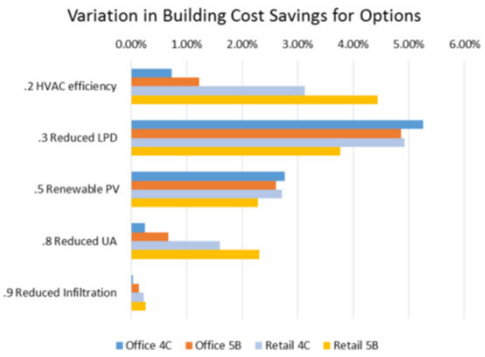
PNNL evaluation of Option Packages

- The C406 Option Packages was introduced into the IECC in 2012 as part of the prescriptive method to achieve an additional 4% energy savings over the prescriptive requirements of the code. The original proposal included three additional options (reduced lighting power density, increased HVAC efficiency and renewables). The 2018 IECC now has eight options to select from. In 2018, PNNL performed an analysis to determine the energy savings potential for each of the eight options and found significant savings differences, as shown to the right.



https://www.osti.gov/servlets/purl/1490280

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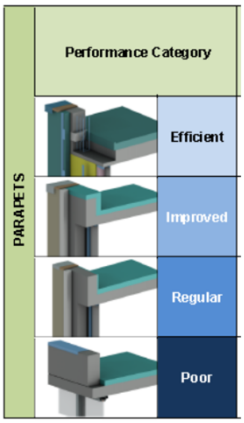
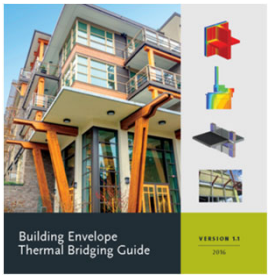
C406.8 Enhanced Envelope Performance

The total UA of the building thermal envelope as designed shall be not less than 15 percent below the total UA of the building thermal envelope in accordance with Section C402.1.5





Building Envelope Thermal Bridging Guide
https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/power-smart/builders-developers/building-envelope-thermal-bridging-guide-1.1.pdf

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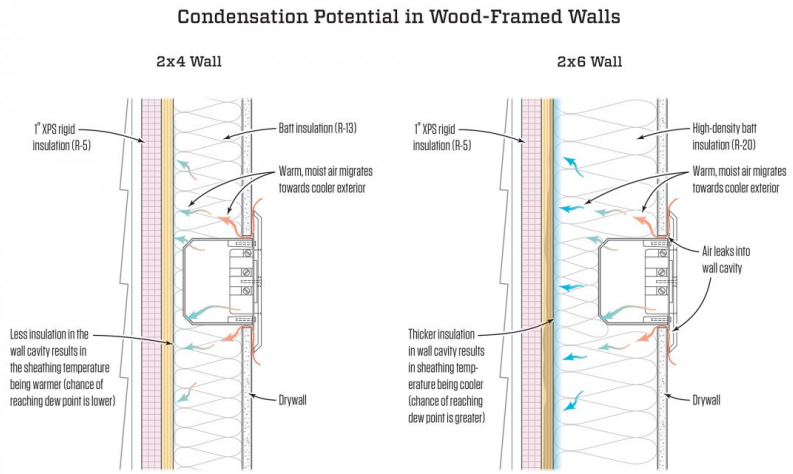
Potential issues with moisture



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Consequence of improperly used insulation

- This rim joist was insulated with fiberglass insulation. Moisture migrated through the insulation and condensed on the rim joist
- Mold was beginning to form on the rim joist
- This was in a brand new house that hadn't even been occupied yet
- Bottom picture is properly insulated and sealed rim joist.

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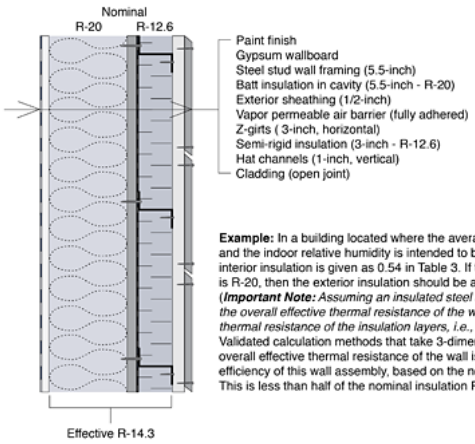
Thermal Bridging is a Big Deal



Example: In a building located where the average minimum January temperature is 14 °F, and the indoor relative humidity is intended to be maintained at 40%, the ratio of exterior to interior insulation is given as 0.54 in Table 3. If the interior insulation in a 5.5 inch wall cavity is R-20, then the exterior insulation should be at least R-10.8.
(***Important Note:*** *Assuming an insulated steel stud wall and metal cladding attachments, the overall effective thermal resistance of the wall will be significantly less than the nominal thermal resistance of the insulation layers, i.e., 20 + 12.6 = R-32.6.*)
Validated calculation methods that take 3-dimensional heat flows into account indicate the overall effective thermal resistance of the wall is only R-14.3. This means that the thermal efficiency of this wall assembly, based on the nominal insulation is 14.3/32.6 = 43.9%. This is less than half of the nominal insulation R-value and may not comply with codes.

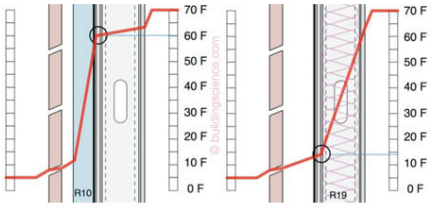


Figure 3: Insulating sheathing as condensation control measure. Continuous exterior insulation on the left, framing cavity insulation on the right. The red line plots the temperature through the two assemblies on a 4°F (-15°C) night. Blue line shows back side of sheathing temperature.

From: https://www.wbdg.org/resources/managing-enclosure-heat-flows

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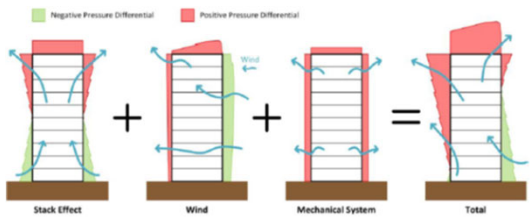
C406.9 Reduced Air Infiltration

- Air Infiltration shall be verified by whole building pressurization testing.
- Measured air leakage rate shall not exceed 0.25 cfm/ft2 under a pressure differential of 75 Pa.
- Building envelope surface area includes below grade building envelope
- Exception: for buildings having over 250,000 SF of conditioned floor area, air leakage need not be conducted on the whole building. Tested areas shall total not be less than 25% of conditioned floor area.



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Air leakage Control

- Canada Mortgage and Housing Corporation has sponsored a lot of building design and performance research.
- This publication addresses Air Leakage Control and is a good source of information on how to design, build, and test for air leakage control.

Link: https://rdh.com/wp-content/uploads/2014/04/Air-Leakage-Control-in-Multi-Unit-Residential Buildings.pdf

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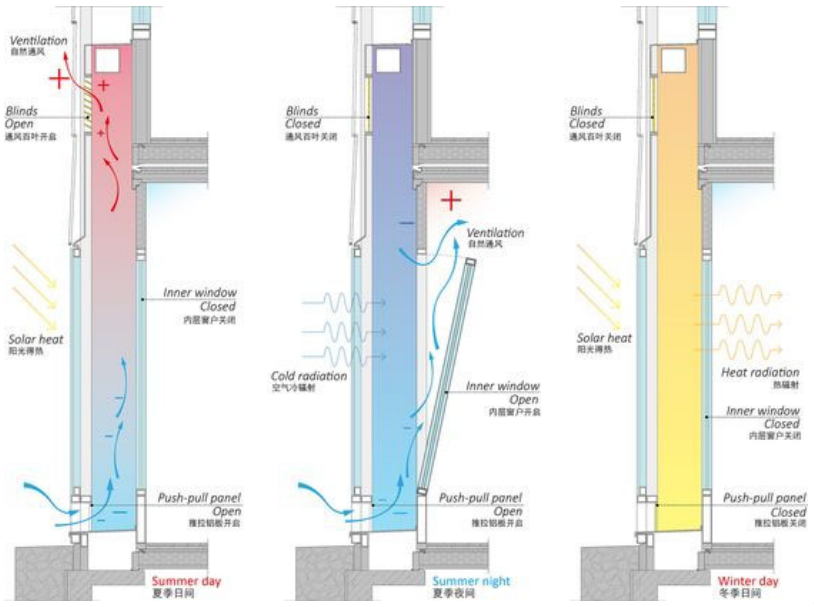

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Energy Conservation Code Compliance for Work in Existing Buildings

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CITY OF CHICAGO
DEPARTMENT OF BUILDINGS
Code Memorandum

To: Department of Buildings Plan Reviewers, Project Managers, Project Administrators and Inspectors

From: Judith Frydland
Commissioner

Date: February 7, 2017

RE: Energy Conservation Code Compliance for Work in Existing Buildings

The Chicago Energy Conservation Code (Chapter 18-13) is designed to promote the effective use and conservation of energy over the useful life of each building. The Energy Conservation Code applies to repairs, alterations, and additions in existing buildings as well as new construction. Because building reuse typically offers greater environmental benefits than demolition and new construction, the provisions of the Energy Conservation Code are to be applied in a flexible manner to promote building reuse.

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Repairs

The following guidelines should be considered when applying the Chicago Energy Conservation Code to work in existing buildings:

1. The Energy Conservation Code is drafted to promote a policy of building reuse, and must not be interpreted in a manner that imposes unreasonable practical or financial barriers to reuse. The Energy Conservation Code does not require replacement of existing building features which remain serviceable.
2. REPAIRS are "the reconstruction or renewal of any part of an existing building for the purpose of its maintenance or to correct damage."

The Energy Conservation Code only imposes minimal requirements on repairs. Repairs include:

a) one-for-one replacement of existing fixtures or elements in mechanical, electrical and plumbing systems (e.g. replacing an existing light fixture, water heater, or furnace) without reconfiguration of the existing system;

b) where the only reconfiguration is mandated by new requirements in the plumbing, electrical, or mechanical code, or to provide greater accessibility; and

c) work done to restore, upgrade, or rebuild an existing condition due to age or following damage, such as a fire or flood.

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Alterations

(3) ALTERATIONS are "any construction, retrofit, or renovation to an existing structure other than repair or addition that requires a permit [or] a change in a building, electrical, gas, mechanical, or plumbing system that involves an extension, addition, or change to the arrangement, type, or purpose of the original installation that requires a permit."

(a) When alterations occur, the Energy Conservation Code only requires existing wall cavities, which are exposed as part of the work, to be filled with insulation. The Code does not require that an existing wall or ceiling cavity, which is exposed during construction, be expanded to accommodate the same amount of insulation required for new construction.

(b) The Code does require walls or ceilings be opened for the purpose of installing insulation. The Code does not require replacement of windows or other elements that are not part of the scope of work.

(c) Insulation is not required to be added to exposed cavities for existing masonry exterior walls when the licensed design professional indicates on the drawings or permit application that the addition of insulation would block air circulation in the cavity, creating moisture problems potentially leading to differential expansion and contraction (cracking) and/or mold.

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Additions

(4) ADDITIONS to existing buildings may comply in a number of ways, but in general, only the newly-built portion must comply with the new construction requirements of the Energy Conservation Code.

(a) In some circumstances, improvements to the energy efficiency of the pre existing building may allow relaxed requirements to apply to the addition.

(b) In many cases, the licensed design professional will submit a report generated by compliance software, such as REScheck or COMcheck to demonstrate compliance for additions and new construction.

(5) For more information on the applicability of the Chicago Energy Conservation Code to ROOFING, please see the memo on roofing requirements dated July 20, 2016.

(6) The Chicago Energy Conservation Code is based on the International Energy Conservation Code (2015), which can be viewed at http://codes.iccsafe.org/

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Roofing Requirements

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Roofing

CITY OF CHICAGO

DEPARTMENT OF BUILDINGS

CODE MEMORANDUM

To: Department of Buildings Plan Examiners and Inspectors

From: Judith Frydland
Commissioner

Date: July 20, 2016

Re: Roof Requirements

The city of Chicago Building Code is performance based, not prescriptive, regarding roof requirements. The only code requirement is the roof must keep the building dry. The code is silent on how to do that. Therefore the purpose of this memo is to clarify acceptable practices regarding roof installation and replacement.

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Definition of terms:

ROOF COVERING REPLACEMENT: Where an existing roof covering is removed, exposing insulation or sheathing and a new roof covering installed. This occurs typically in ballasted single ply roof systems, lengthens the life of the insulation in serviceable condition, and is allowed where the energy usage of the building does not increase.

ROOF REPAIR: Reconstruction or renewal of any part of an existing roof for the purposes of its maintenance.

ROOF REPLACEMENT: The process of removing the existing roof covering, repairing any damaged substrate including insulation or sheathing and installing a new roof assembly.

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Constraints on installation of code required amount of R-value on existing buildings:

The energy conservation code acknowledges that existing buildings cannot always meet the requirements of the new construction code. In regards to re-roofing projects, there is language in the code in section C503.1 and R503.1 which allows for accommodation of existing constraints. The City of Chicago has consistently interpreted this to allow for a reduction in the required amount of insulation if the height of the installation would require other elements of the building to be changed where that wasn't part of the scope of work already. This means that parapet heights, equipment curbs, skylight curbs, window sills, door thresholds, and other such elements with flashing into the roof system, are not required to be increased in height solely to provide adequate depth for code required insulation.

The Department of Buildings has not required special administrative relief for this situation, just a statement on the application as to the amount of insulation to be provided and a description of the constraint preventing full compliance. The minimum amount of insulation per the state of Illinois amendments is R-3.5 per inch. In no case, shall the amount of insulation by less than what was there prior to the work. If the occupancy changes and increases the amount of energy used in the space, then the new construction standards apply and this exception is no longer available.

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#40. R502, R503 Additions / Alterations

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R503.1 Alterations

Alterations to any building or structure shall comply with the requirements of the code for new construction. Alterations shall be such that the existing building or structure is not less conforming to the provisions of this code than the existing building or structure was prior to the alteration.

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R503.1 Alterations Exception

The following are not required to comply provided the energy use of the building is not increased:

1. Storm windows over existing fenestration
2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation
3. Construction where the existing roof, wall or floor cavity is not exposed
4. Roof recover (See definition)
5. Roofs w/o insulation in the cavity and where the sheathing or insulation is exposed during the reroofing shall be insulated either above or below the sheathing
6. Surface applied window film installed on existing single pane fenestration to reduce solar heat gain provided that the code does not require the glazing or fenestration to be replaced

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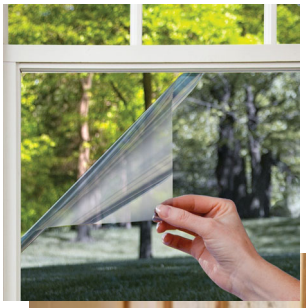
R503.1 Alterations Exception



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R503.1.1 Roof Membrane Peel & Replacement

*This provision is narrow and not likely to apply as flat roofs are rarely replaced before there is a leak which would require work to be carried out on the roof insulation, eliminating the ability to use the provision.

Roof membrane peel and replacement – Where an existing weather resisting roof membrane alone is removed, exposing insulation or sheathing and only a new weather resisting roof membrane is installed.

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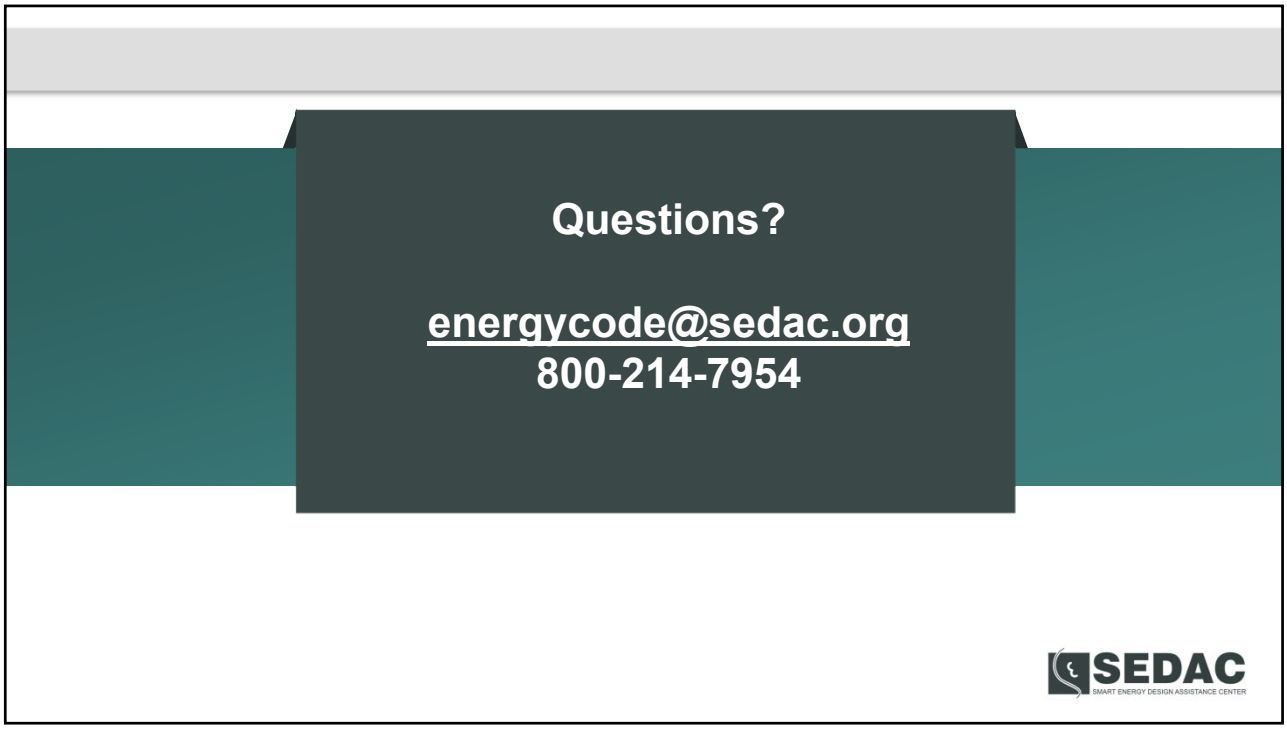
Questions?
energycode@sedac.org
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